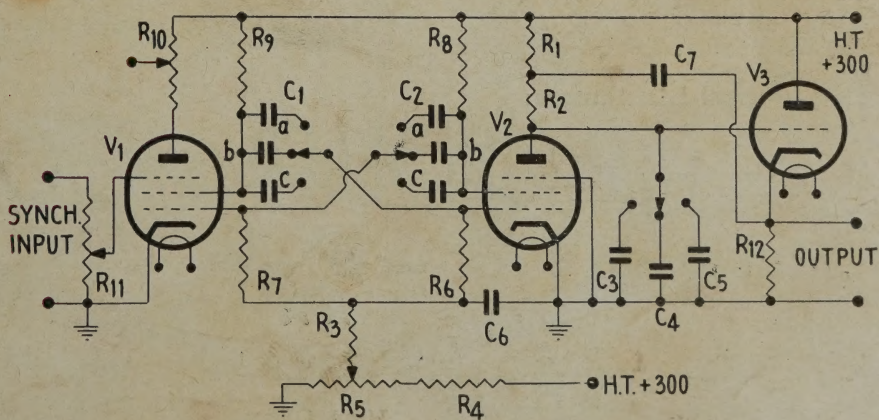
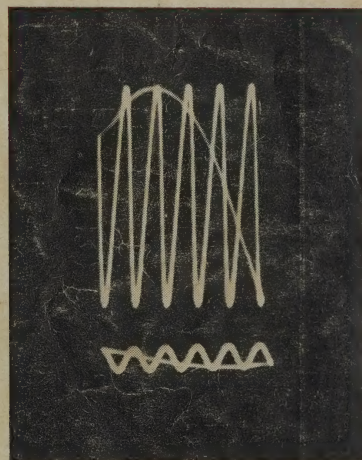
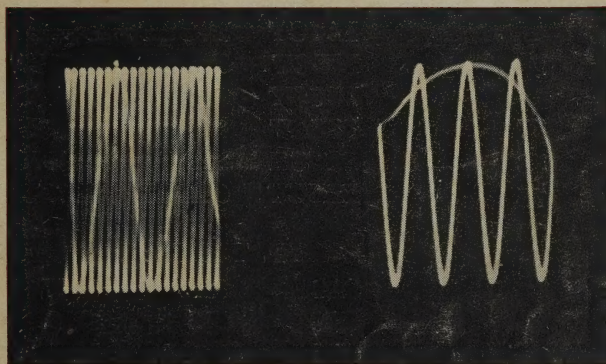


# RADIO and ELECTRONICS

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*In this Issue:*

A HARD-VALVE LINEAR TIME-BASE

APRIL 1, 1948

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Vol. 3, No. 1

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OUR COVER this month shows the circuit and some of the wave-forms of a special time-base designed in our laboratory and described in this issue.

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## SOME ASPECTS OF DISTORTION

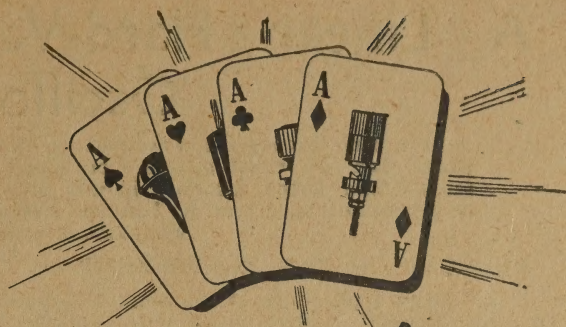
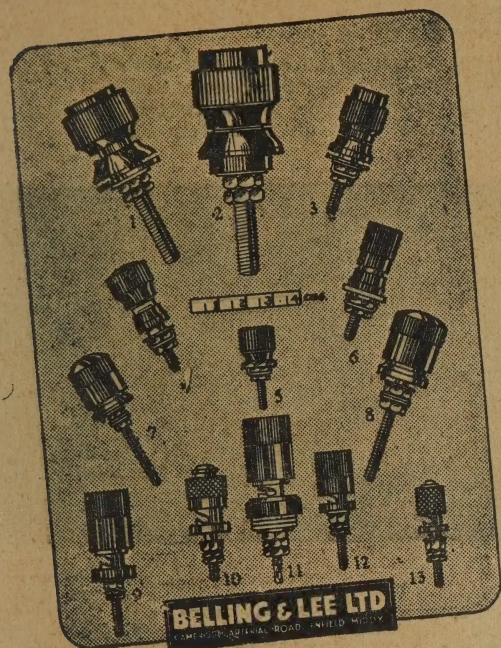
The term "distortion" covers a multitude of sins that beset the electrical reproduction of music. Broadly speaking, it may be defined as "the introduction into reproduced sound of effects which were not present in the original." This definition includes quite a number of factors which, if thought of as distortion, are dismissed as impossible to remedy, but which are more often ignored altogether. We refer to such things as the lack of the binaural effect, and the inability of most systems to reproduce music at a volume level comparable with that of the original. Even some of the more disturbing types of distortion, such as intermodulation, have only recently been brought to light, and ways of measuring them devised. In addition, there are ways of "correcting" an amplifier that of necessity introduce distortion themselves, unless very special precautions are taken.

The evaluation of the commoner and most important types of distortion, such as harmonic distortion and frequency distortion, is quite easily accomplished with one important proviso, namely that the measurements are done at a single frequency, or at best, a series of single frequencies. The importance of this proviso on the value of the results obtained is even now only too little realized. Take the case of a system handling the complete range of musical frequencies. This means that at any one instant the system is called upon to reproduce a highly complex waveform representative of a great number of individual frequencies. Single frequency tests will not necessarily give any indication of the system's performance under normal operating conditions, with the result that while such tests are undoubtedly useful, and form a valuable engineering yard-stick with which to compare the electrical performance of reproducing systems, they do not necessarily give any guarantee that the acoustical performance of the systems compared will tally, even qualitatively, with their results. It may truthfully be said, however, that to a first approximation, single frequency tests give useful answers, and that such measurements are a great deal better than no measurements at all; but the fact remains that they can also be entirely misleading.

Take, for example, the question of frequency response. It may seem sufficiently well established that each unit in a reproducing system should ideally have a level response between the upper and lower frequencies at which "sound" waves cease to affect the human ear. No one would readily dispute this, but have we any guarantee that such a statement has any meaning when applied to a loud-speaker? It would have, were it possible to produce a speaker whose response curve, measured by the ordinary method, was not a succession of peaks and troughs, rather like the highly magnified image of the edge of a razor blade. The fact is, that such a speaker has not yet been made, and that loud-speaker response curves, measured as actual acoustical output, show that even the best speaker is a highly non-linear device.

A start in the right direction has been made by the introduction of intermodulation measurements as supplements to single frequency tests but even these are clearly an over-simplification of actual conditions. We believe that attempts have also been made to assess the characteristics of loud-speakers by a method in which the speaker is excited simultaneously by all frequencies, the source of input being thermal noise, derived from a saturated diode. By means of a heterodyne system, and the use of the noise output of the speaker to modulate a high frequency carrier, the output of the speaker at virtually single frequencies over the audio range can be measured. Thus, assuming that the noise source gives equal output at all frequencies, a response curve is obtained that shows the performance of the speaker while loaded at all frequencies.

This scheme appears to approximate actual working conditions much more closely than single frequency tests, but even here, have we a method that bears any relation to the reaction of a listener to the musical output of the speaker?



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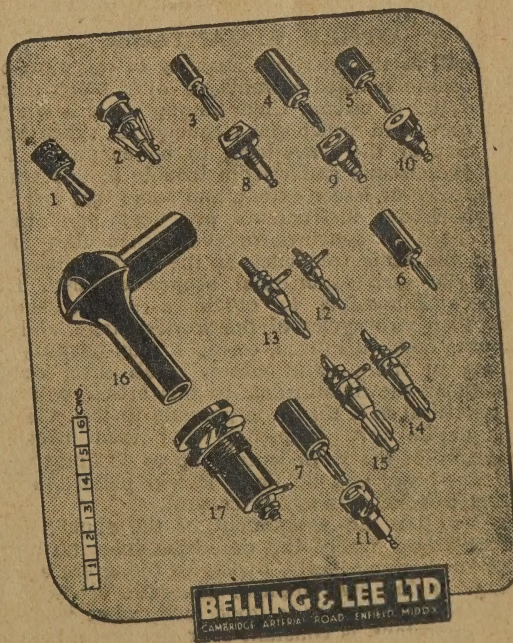
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# A Linear Hard-Valve Time-Base for Oscilloscopes

For some purposes it is desirable to have a time-base which is much more accurately linear than the usual gas-tube or simple hard-valve time-base found in most oscilloscopes. The design described in this article is ideal for incorporation in the circuits of new instruments, or can be built as a separate unit for use when an accurately linear time-base is needed.

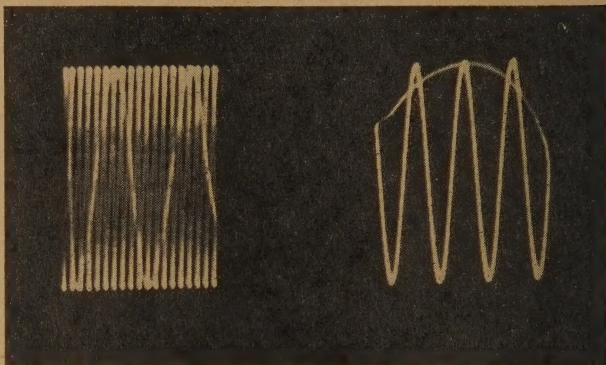
## PURPOSE OF THE INSTRUMENT

There are many applications of the oscilloscope in which a really linear time-base is not only desirable, but entirely necessary. One such application is the examination of wave-forms other than sinusoidal in shape. For example, when square-waves are being examined, as they often are in work involving pulses of any sort, a non-linear time trace can lead to quite erroneous conclusions regarding the shape of the wave being observed. Similarly, if for any reason it is desired to estimate what fraction of a cycle of some reference frequency is taken up by the phenomenon under observation, it is almost impossible to do so unless the time-base is linear, for if it is not, each succeeding cycle of the reference voltage occupies less space on the trace, and fractions of a cycle cannot be read with any accuracy. Similarly, in measurements where wave-form distortion is estimated by comparison of a wave with a sinusoidal wave, deviations are hard to see if the picture is distorted in any case, through the non-linearity of the trace. Even if one has no special applications in view, it is very pleasant to have a good time-base in one's oscilloscope, since the pictures obtained are much easier to look at if mental allowance does not have to be made for obvious distortion.

## OTHER ADVANTAGES

As well as the excellent linearity of this time-base, it has some decided advantages over more conventional types of circuit. Chief among these is the very great ease with which the frequency is synchronized with that of the wave-form to be examined. Most time-base circuits suffer from trouble in this respect, to a greater or lesser extent, and some that are found in commercial instruments are very poor indeed, being hard to synchronize even when they are to run at the same frequency as the work-voltage. The writer has seen commercial 'scopes in which it was virtually impossible to obtain a picture showing more than two cycles of the work-voltage, and even that was badly distorted, owing to non-linearity. The locking of the present circuit is all that could be desired, as the illustrations to this article will show. So uncritical is it that it is possible to lock the time-base at its own frequency, and then sweep the frequency of the work-voltage up to 40 times that of the time-base, and obtain a locked picture, **without having to touch the synch. control.**

In addition, no adjustment of the synch. control can be found where the time-base folds up and refuses to work properly, owing to too great a synch. voltage having been applied. The ratio of sweep time to flyback time is quite good, and, what is possibly more important, is constant over the useful frequency range of the time-base. If necessary, the flyback may be blacked out, since the circuit automatically provides a wave-form that can be applied to the grid circuit of the C.R.T. This facility is available on all



Left, Fig. 2, showing an 80 kc/sec. wave on a 4,000 c/sec. time-base. Note that the flyback is linear as well as the main trace. Right, Fig. 3, showing a 4,000 c/sec. wave on the same time-base. These two photographs were taken without shifting the synch. control from where it was set for the second picture, which was taken first. Both illustrate the admirable linearity achieved.

frequency ranges, but if the extra complication is undesirable, it can simply be left unconnected.

## DISADVANTAGES?

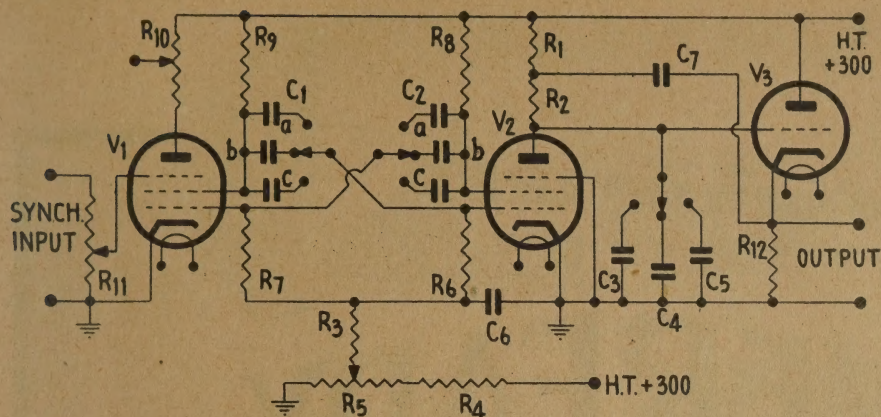
If the circuit has a disadvantage, it is that of using three valves, instead of the more usual one or two. However, this is hardly a drawback where excellence of performance is the main thing to be considered.

In spite of its three tubes, the circuit has no critical adjustments, and in fact is much easier to get going than the single-tube "transitron" circuit. A three-pole switch is needed, and a few more components, but this at a small price to pay for the ease of operation and extreme linearity achieved.

## PRINCIPLE OF OPERATION

Essentially, the circuit consists of a multivibrator, which uses pentodes in place of the more usual triodes, and a cathode-follower, specially connected so as to correct for any non-linearity in the saw-tooth wave fed to it. The cathode follower also provides a convenient low-impedance output, so that the time-base may be conveniently located on the chassis, and long output leads run, if necessary. The low output impedance also prevents the input resistance of the succeeding amplifier tube from shunting the time-base condenser, with consequent reduction of linearity.

The purpose of using pentodes in the multivibrator instead of triodes is two-fold. First, the multivibrator action takes place with the control grids and screens of the pentodes acting as triodes. Thus, if the suppressors and plates of the pentodes are ignored, the circuit is simply that of a triode M.V. With this action going on, the plate circuit of either pentode is isolated from the circuit that determines the frequency of oscillation, namely the M.V. If a resistor



- $R_1, R_2, R_3, 50k.$   
 $R_4, R_8, R_9, 25k.$   
 $R_5, 100k. \text{ pot.}$   
 $R_6, 1 \text{ meg.}$   
 $R_7, R_{12}, 100k.$   
 $R_{10}, 50k. \text{ pot.}$   
 $R_{11}, 500k. \text{ pot.}$   
 $C_{1a}, C_{2a}, 0.01 \text{ mfd.}$   
 $C_{1b}, C_{2b}, 0.001 \text{ mfd.}$   
 $C_{1c}, C_{2c}, 0.0001 \text{ mfd.}$   
 $C_3, 0.5 \text{ mfd.}$   
 $C_4, 0.05 \text{ mfd.}$   
 $C_5, 0.005 \text{ mfd.}$   
 $C_6, C_7, 1 \text{ mfd.}$   
 $V_1, V_2, V_3, 6AC7/1852.$

is placed in the plate circuit of either pentode, a square-wave output can be obtained that is considerably improved compared with the waveform of a simple multivibrator. That is, the output waveform does not have the comparatively slow rise with the pronounced curvature near the top that is characteristic of the triode M.V. In fact, the output is as good a square-wave as is got when a separate squarer is used to follow a normal M.V. The time constant of the grid of  $V_2$  has been made ten times that of the  $V_1$  grid circuit. This causes the multivibrator to have a mark-space ratio of approximately 1:10, so that the waveform at the plate of  $V_2$  would have the shape shown in Fig. 1a, were it not for the fact that one of the bank of condensers is connected from plate to earth of  $V_2$ . In other words,  $V_2$  acts as an electronic switch, which acts as follows. When  $V_2$  is cut off (during the period marked  $t_1$  on Fig. 1), the time-base condenser, whichever is in circuit, is able to charge up through  $R_1$  and  $R_2$  in series. When  $V_2$  is conducting (during the time  $t_2$  on Fig. 1a) it acts as a leak, through which the condenser is able to discharge. This action is shown in Fig. 1b, from which it can be seen that the long charging period constitutes the linear rise of the saw-tooth, while the short discharge is the flyback. This is the fundamental action of the time-base circuit, and is unaffected by the cathode-follower  $V_3$ .

### CIRCUIT DETAILS

The method of varying the repetition rate of the time-base is noteworthy, as it succeeds in varying the frequency of the multivibrator without appreciably affecting the mark-space ratio. This is important, as the latter determines the length of the flyback compared with the trace time. Most ordinary ways of controlling the frequency of a M.V. also affect the mark-space ratio, but the one used here does not, because it has no effect on the time constants in the grid circuits. The scheme is to return the grids of the M.V. tubes to a voltage divider connected between H.T. and earth. Thus the bias on the valves is either zero or positive by a controlled amount. The mechanism of this form of control is quite readily understood when it is remembered that the frequency is controlled by the time taken by the grids to reach cut-off from the negative direction, after the previous pulse of plate current has charged the grid condensers to a high negative potential. Thus each grid circuit's time constant controls the length of one half-cycle of

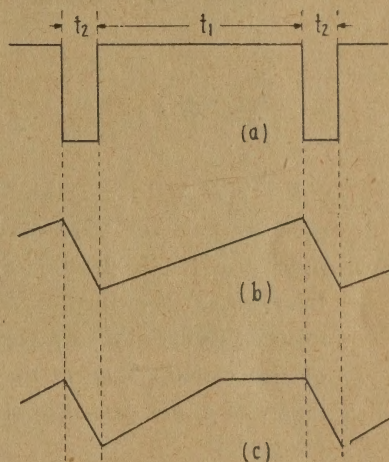
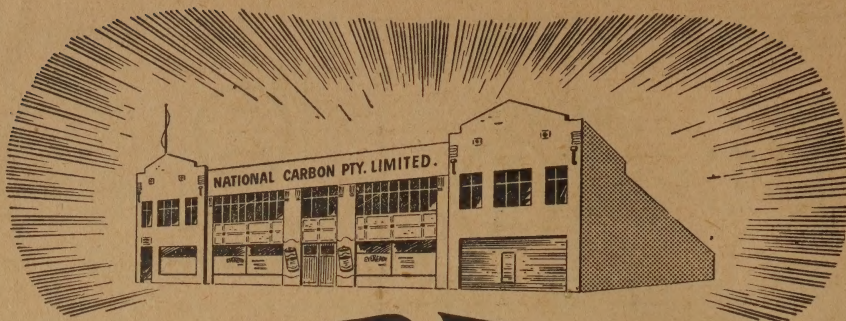


Fig. 1, showing the important wave-forms in the circuit. At (a) is the wave-form at the plate of  $V_2$  with the charging condenser omitted. (b) is the saw-tooth actually found at the same place when the circuit is operating. (c) shows what happens if the charging condenser is too small.

the oscillation. Obviously, altering the time-constant of either or both of the grid circuits will affect the frequency, but it is not so obvious that the bias on the tubes will do so.

Since each pulse of plate current has the same amplitude, owing to the fixed values of the H.T. voltage and the tubes' plate current, the grid condensers always charge by the same amount on each charging cycle. Now, if the grids have no standing bias, the condensers have to discharge from a voltage  $-E$  to, say,  $-4$  volts, the cut-off bias for the tubes, before the latter will conduct again. But if the grids now have a positive bias of, say, 100 volts, the condensers can charge only to a value of  $-E + 100$  volts. Consequently, they will take a correspondingly shorter time to discharge to the point where the grid is  $-4$  volts with respect to the cathode. Thus the frequency of oscillation is raised when the grids are biased positively. It is clear, too, that if the grids are both biased by the same amount, the effect on each half-cycle must be identical and that, in consequence, the relative duration of the half-cycles, or in other words the mark-space ratio, will remain unaffected.



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The inequality of time constants in the grid circuits of  $V_1$  and  $V_2$  have been mentioned above; this is achieved by using identical condensers and making one grid-leak ten times the other. This removes the necessity for very small condensers, which are undesirable, since the valve capacities would then be a substantial part of the total circuit capacity, and since they are mainly in shunt with the tube elements, the result would be difficulty in obtaining the requisite performance at the higher frequencies. The main drawback would be that the flyback time would no longer be under control, and would become a large part of the cycle.

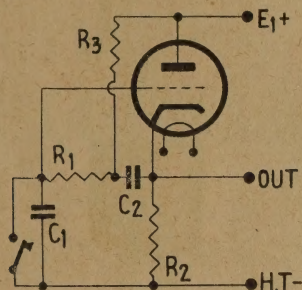


Fig. 4. This shows the part of the circuit that is responsible for making the trace linear. The multi-vibrator acts as the switch across  $C_1$ , the charging condenser, and the output of the cathode-follower is fed back to the charging circuit by  $C_2$ .  $R_3$  and  $R_2$  in parallel form the effective load for the valve.

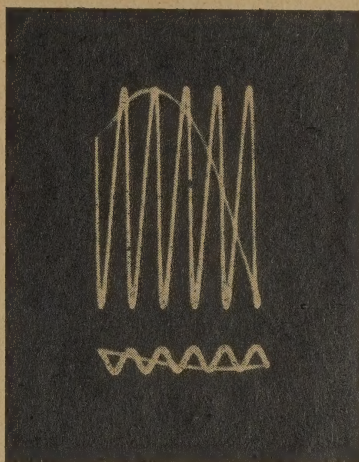
The values of the charging condensers  $C_3$  to  $C_9$  are not critical, but require careful choice if the best is to be obtained from the time-base. If they are too small, the result is that they become completely charged before the end of the M.V. cycle. This results in an output wave in which the top of the triangle has been wiped off, similar to that shown in Fig. 1c. In addition, the linearity is poor, because the whole charging curve is being used. This is exponential, and although the cathode-follower linearising circuit is very effective, it cannot compensate for a completely exponential trace. On the other hand, when the condenser is made large, the linearity is improved, but at the same time the output voltage becomes less. The upper limit is therefore set by the amount of amplification available after the time-base. The values specified in the component list give an output of approximately 45 volts peak-to-peak at the low-frequency end of each range. It should be pointed out at this juncture that the output voltage of this kind of time-base is not constant when the frequency is varied with  $R_5$ . Since the time-base condenser charges in a linear manner, the amplitude is inversely proportional to frequency. Thus, if each range has a frequency variation of 10:1, the amplitude will be only 4.5 volts peak at the high-frequency end of the range. This is a slight inconvenience, but is readily compensated by means of the X-gain control. It can even be made use of for frequency measurements, since, if the time-base length and frequency are known for a particular setting of the gain control, the frequency can easily be calculated from the length of the trace if the gain control setting has not altered. However, the main point is that the amplifier to follow the time-base must be designed on the basis of the minimum output of the latter. In this instance, it must be possible to get the required

output from a saw-tooth of 4.5v. p-p, and when this has been done, there will be more than enough gain for all frequencies.

The values of the time-base condensers have been chosen so that the output voltages on all frequency ranges correspond closely.

### ACTION OF THE CATHODE-FOLLOWER

The time-base itself has been described, with all reference to  $V_3$  purposely omitted. The saw-tooth output appears at the plate of  $V_2$ , and could be taken from that point, but the cathode-follower buffer has some important advantages, which were outlined



Figs. 5 and 6. These were photographed without adjustment of the synch. control, this having been set before the top picture was taken. The work frequency is 24,000 c/sec. and the time-base is at 4,000 c/sec.

above. The grid of  $V_3$  is directly coupled to the plate of  $V_2$ , so that it is always quite highly positive in potential. However,  $R_3$  has the high value of 100k., with the result that the cathode is highly positive, too, and the resultant positive bias on  $V_3$  is not as high as might be expected. When the time-base condenser is charging, the grid voltage of  $V_3$  rises with that on the condenser. This causes the cathode voltage of  $V_3$  to follow; the output of the cathode-follower is coupled through  $C_7$  to the charging resistor chain, so that the rise in cathode potential is transferred across  $R_2$ . Now, since non-linearity of the trace is due to the rate of charge falling off towards the end of the charging period, the increased voltage across  $R_2$  tends to make the condenser charge more quickly, thus compensating for the normal drop in charging rate. The effectiveness of this circuit is strikingly demonstrated by purposely making  $C_7$  too small for good linearity without  $V_3$  in circuit. The linearity, or lack of it, can be shown up by using the time-base to display several cycles of a sine-wave, as in the photograph herewith. Then,  $V_3$  is plugged in, and the crowding together of the cycles at one end of the trace will be seen either to disappear altogether, or else to be greatly reduced. The low output impedance of the cathode-follower is very handy, in that it simplifies the layout of the whole circuit of the X-axis. Thus the time-base can be placed so that the controls are conveniently situated with respect to the panel, and the X-amplifier so as to have its output close to the

C.R.T. base. If this involves a run of some distance between the time-base output and the amplifier input, it does not matter, because the low output impedance of the cathode-follower minimises hum-pick-up and the bypassing effect of stray capacities on the high frequencies.

### PERFORMANCE OF THE TIME-BASE

Much could be written on the performance of this unit, but a better idea may be gained from the accompanying photographs. All of them were taken with exposures of half a minute or more, and this alone gives a good idea of the stability of the picture. Had there been any jitter such a long exposure would have shown it up very readily. The relative time-base and sine-wave frequencies are indicated in the captions to the pictures. All of them indicate a high order of linearity, and also the ease with which the frequency of the base may be locked, even when the work-voltage is 40 or more times lower than the time-base in frequency. Figs. 5 and 6 indicate how uncritical is the circuit with respect to locking. The two photographs were taken in the following manner. First, the time-base was locked so as to show six cycles of the 24 kc/sec. work voltage. The synch. potentiometer was fed from the same terminal as the Y plate of the C.R.T., i.e., the output of the audio signal generator. The top picture was then taken. Then, without touching any other controls, the signal generator output was reduced to  $\frac{1}{10}$  the previous output, and the result was photographed. It can be seen that the locking is so stable that even with this range of input voltage, not only has the picture remained locked, but even the number of cycles in the picture has not changed, indicating that the time-base is still running at the same frequency. The linearity can be judged by the regularity of the spacing of the waves.

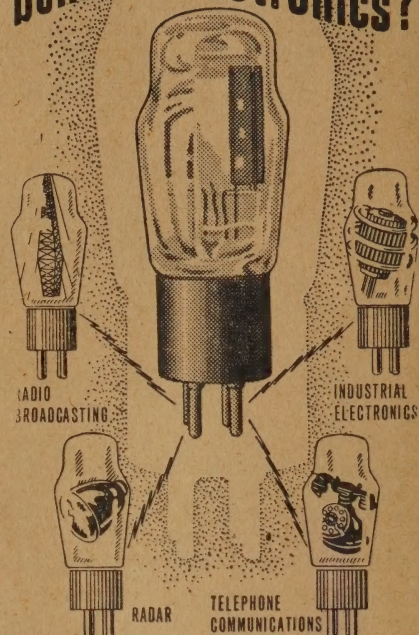
A notable point is that Figs. 1 and 2 were taken without the synch. control having to be adjusted. In practice, the signal generator frequency was run up to 100 kc/sec. from 16 kc/sec., and every time the frequency came to a multiple of the time-base frequency, a locked picture was obtained.

### RANGES TO BE USED

If the time-base is to be duplicated, there is no need to stick rigidly to the values of  $C_1$  and  $C_2$  and  $C_3$  given in the component list. These can be modified to give any desired range of frequency, in any number of separate ranges. The important thing to note is that if the waveform is to be preserved,  $C_3$  must always be made 50 times the value of  $C_1$  and  $C_2$ . Also, it is necessary to know that the maximum variation that can be obtained from the circuit is approximately 10:1 on any one range. The values specified in the component list have been given on this basis, and give quite an accurate idea of the frequencies that will be obtained for given values of the condensers. If a range is wanted that starts at some other frequency, the condensers must be changed in inverse proportion to the frequency. For instance, if a range is wanted to have a minimum frequency of 50 c/sec.,  $C_1$  and  $C_2$  would be  $0.01 \times 20/50 = 0.004$  mfd. Then, to keep the linearity and output voltage the same as before,  $C_3$  would be altered to 0.2 mfd.

If a 10:1 range is required, it is always advisable to check that overlap is obtained, for with ordinary (Continued on page 48.)

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## PART II

The principle of the voltage doubler may be extended so that a tripler, quadrupler, or any multiple of voltage input may be obtained. The diagram of Fig. 11B shows a circuit for a voltage multiplication of  $N$  times.

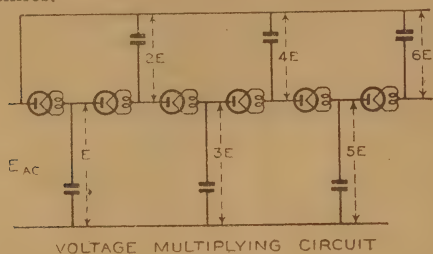
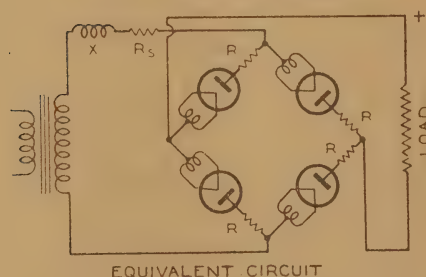
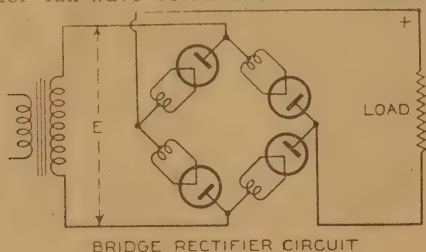


Fig. 11B.

## BRIDGE TYPE RECTIFIER

The bridge type rectifier is used where a centre tapped plate transformer is not available or where the peak inverse voltage of the tube in a full-wave circuit exceeds the tube rating. The bridge type rectifier uses two tubes in series for rectifying each half-cycle, and therefore requires a total of four tubes for full-wave rectification. In addition, three



$R_s$  = EQUIVALENT TRANSFORMER RESISTANCE REFERRED TO SECONDARY.

$X$  = EQUIVALENT TRANSFORMER REACTANCE REFERRED TO SECONDARY.

Fig. 12.

separate filament transformers or windings are required. The operation of the bridge type circuit is identical to the operation of the full-wave rectifier except that two tubes are always in series, and therefore the tube drop is twice as great as the tube drop in the full-wave rectifier. Fig. 12 shows the circuits of the bridge rectifier circuit.

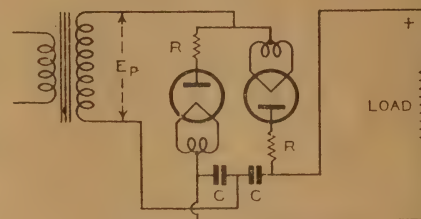
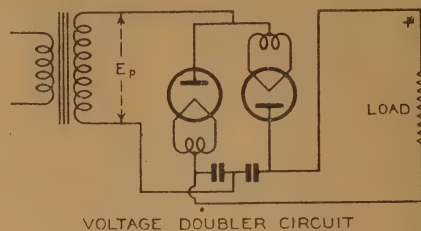


Fig. 11A.

## REGULATION

Regulation of a power supply unit must be considered from two points of view, the regulation under steady state loads and the regulation under suddenly applied loads. Receivers using Class A output systems normally operate at constant load, the only variation in load being caused by the variation in the strength of the input signal which determines the bias voltage on the grids of R.F. and I.F. stages, and therefore the plate currents. This load variation is relatively small, and has but slight effect on the output voltage of the rectifier system.

Receivers using Class A-B or Class B output stages are subject to sudden drains on the plate supply on modulation peaks of the received signal. These load variations may be large enough to produce peak loads two or more times the normal load on the rectifier. The rectifier must be capable of supplying these peak loads without too great a voltage drop, or serious distortion will result. The large variation in voltage that occurs in a power supply system having poor regulation imposes a severe strain on the filter condensers at light loads or when the set is warming up. This latter condition may be minimized by using a rectifier tube whose heating time is the same as the heating time of the set tubes.

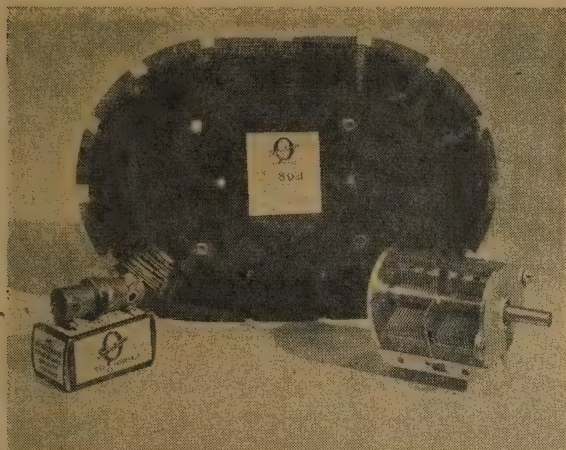
The poor regulation of a power supply can be attributed to any one or more of the following factors:—

- (1) Poor voltage regulation of the plate supply transformer.
- (2) High voltage drop in the rectifier tube.
- (3) Filter input condensers too small for given load.
- (4) Chokes having too high resistance.
- (5) Using output condensers having capacities too small for change in load.

These conditions are dependent on the type of rectifier circuit and filter circuit used, the choke input rectifier inherently having better regulation

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characteristics than the condenser input rectifier.

The size of the filter output condenser does not affect the steady state regulation of the power supply, but its value is of great importance in the dynamic regulation of the power supply. The dynamic regulation of a power supply differs from the steady state regulation in that the size of the choke and filter output condenser are of prime importance.

and the current variation. This voltage is also impressed across terminals of any other circuits connected to the same power supply. If there is any other coupling between the circuits, the common impedance may cause an unstable condition and produce oscillation. A high mutual impedance in the power supply is the usual cause of "motor-boating" in high gain amplifiers.

To reduce the tendency to "motor-boating" the power supply regulation must be reduced to a minimum. This can be done by proper design and the liberal use of condensers in the filter output circuit and the use of low resistance filter chokes and tubes having a small voltage drop. The use of a bleeder resistance at the filter output terminals will help in reducing the percentage static regulation, but will have little effect on the dynamic regulation.

The best results are obtained by using voltage controlled rectifier systems in which the percent. regulation can be kept down to less than one-half of 1 per cent.

To improve the dynamic characteristics of the rectifier, the voltage regulator must be controlled by the output voltage and must have a time constant low enough to be able to follow

the fastest variation in voltage or current produced by the load. In the average circuit, the frequency at which the system becomes unstable is quite low, so that extremely small time constants are not required. A time constant for an automatically regulated power supply of 0.1 seconds is normally low enough. Special amplifications may require other values. These can be determined from the nature of the load.

(To be continued.)

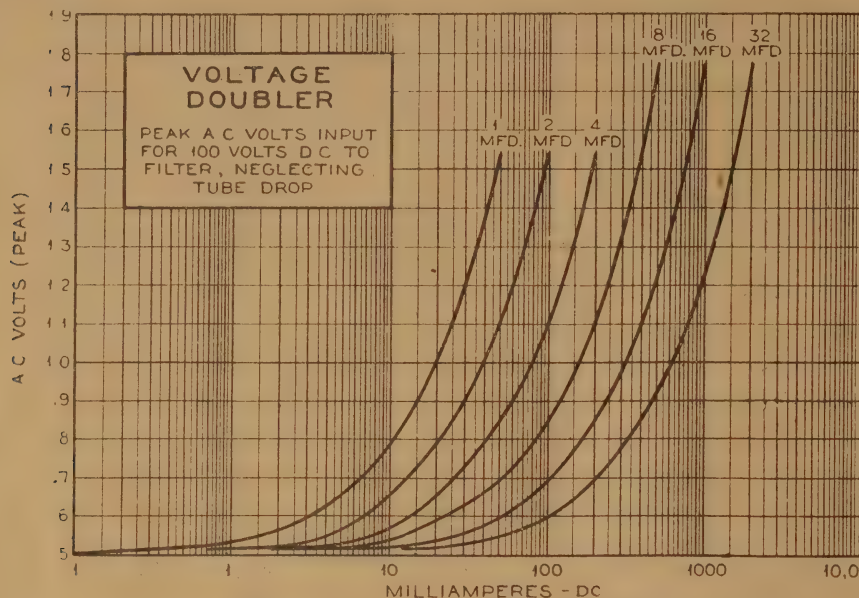


Fig. 10.

For a constant voltage supply or where the rate of change of load is more than the rate of change of current or voltage of the filter input, the dynamic regulation can be reduced to a minimum by making the capacity of the filter output condenser as large as possible. Doing this not only improves the dynamic regulation, but also increases the ripple attenuation of the filter. The minimum size filter output condenser that can be used is theoretically given by

$$C = \frac{L}{R^2} \text{ mfd.}$$

$L$  = inductance of series choke in henries

$R$  = average load resistance.

The series resistance of the choke must be small compared to the load resistance, but as this is a condition for good steady state regulation, it is easily met.

Regulation or the drop in voltage at the filter output terminals with an increase in load causes the filter output terminals to look like an impedance when viewed from the load. By this is meant that the power supply can be considered as a perfect power supply without regulation and a series resistor. Aside from the variation in voltage and its attendant disturbances in the system, the power supply system having a higher percentage of dynamic regulation causes coupling between circuits. Any current fluctuations in a connected circuit will produce a voltage across the power supply terminals equal to the product of the power supply impedance

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# TONE-CONTROL SYSTEMS

By C. R. LESLIE

## PART I (Continued)

Fig. 8 shows a more ambitious circuit, in which voltage from the anode is fed back to the grid via a potentiometer system consisting of  $R_1$ , bank of condensers,  $C_1$ ,  $C_2$ ,  $C_3$ , and potentiometer  $R_2$ , whose slider is earthed via  $C_4$  and  $R_3$ . When  $R_2$  is fully out (i.e.,  $C_4$  and  $R_3$  are shorted to earth) and the switch  $S$  at  $C_1$ , the response is approximately linear. With  $S$  at  $C_2$ , there is an increase of impedance to low frequencies, and hence less feedback relative to the high frequencies; the  $C_3$  position increases this

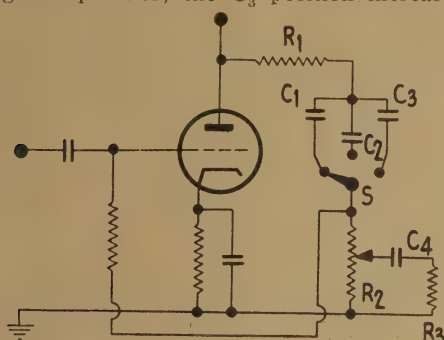


Fig. 8.

effect to give maximum bass "boost." Treble "boost" is introduced by moving the slider of  $R_2$  away from earth and thus reducing the impedance of this section of the divider system, the reduction being proportional to the increase in frequency. The maximum treble "boost" effect is obtained when  $R_2$  is fully "in." With careful design, the bank of condensers makes this system smoothly variable over a wide range.

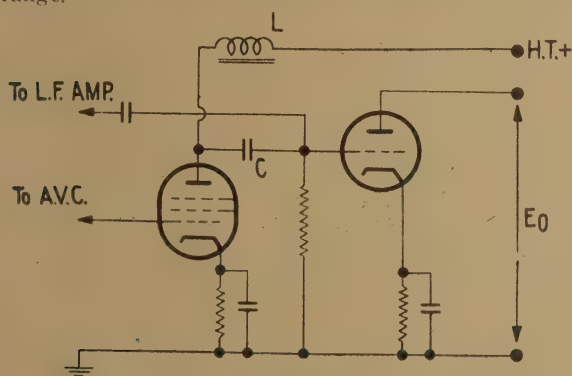


Fig. 9.

### (4) Automatic Tone Control:

This system is not commonly met with in commercial receivers because of the additional complication and expense, as it entails the use of at least one extra valve, which, from the customer's point of view, is not doing anything very useful. As the name implies, the valve is used as a variable impedance, usually as a variable resistance. The basic prin-

ciple of the system is shown in Fig. 9. When a strong signal is received, the A.V.C. voltage is high, so that the grid of the valve is considerably negative to cathode, with resulting high plate impedance (denoted by low plate current); high audio frequencies are then prevented from passing through the condenser  $C$ , as the impedance of the choke is also very high. With a weak signal (i.e., low volume), the A.V.C. voltage drops and reduces the grid bias and so lowers the plate impedance to permit a proportion of the higher frequencies to pass through the condenser  $C$  and the valve, and so give a bass "boost" effect which is particularly desirable at low volume levels.

## GRAMOPHONE AMPLIFIERS

Although a radio set may be constructed to accept gramophone pick-up it may be found that the bass

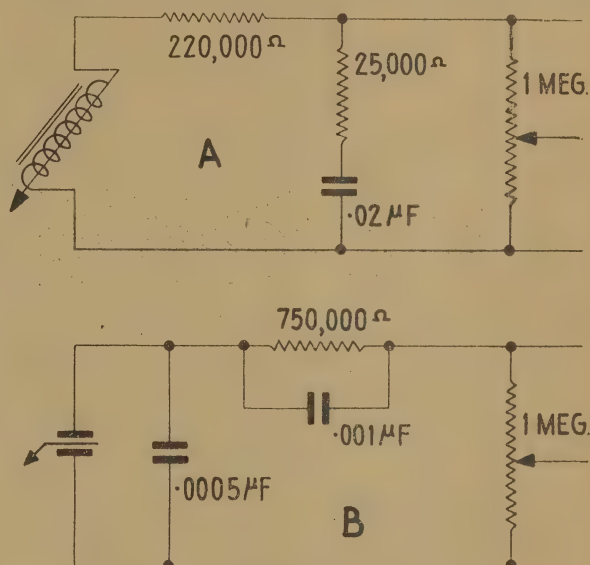


Fig. 10.

lift is insufficient for the satisfactory reproduction from records; it is a simple matter to fit a bass "boost" filter in the pick-up leads. Fig. 10 (A) shows a suitable circuit for an average magnetic pick-up, with values of components designed for a 6 db. lift per octave, which should be sufficient to cover any recording loss. If the pick-up is of the crystal type (and does not possess bass boost characteristics) a suitable circuit will be found in Fig. 10 (B).

In our previous article we made mention of "needle scratch" filters; these are not compulsory by any means as modern improvements in recording and pick-up design have almost eliminated any such necessity. If "scratch" is present, the insertion of a filter will entail the by-passing of frequencies of above 5,000 c/s. so that much brilliance will have to be sacrificed. Such a filter would take the form of a condenser and, preferably, a variable resistance as used for bass "boost." It is better, therefore, to check up on the needle pressure first—this should be just

heavy enough, and no more, to keep the needle moving freely in the record groove.

Many readers, who wish to get the best out of their records, may prefer to construct their own amplifiers, and when so doing may consider incorporating a remote control of volume and tone. For reasons already stated, this should come into the circuit as early as possible where signal amplitudes are lowest, so that the compensated signal can be

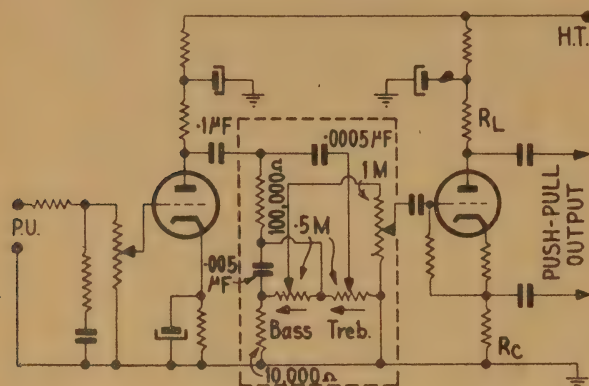


Fig. 11.

subsequently amplified. Fig. 11 shows a suitable circuit for use with a push-pull output stage. The pick-up input is fitted with the bass "boost" circuit of Fig. 10 (A) with an overriding pre-set volume control feeding the grid of the first valve. The portion enclosed by the broken line is the combined remote tone and volume control whose output feeds the grid of the phase-splitter valve. The control box or container can be some four or five yards from the amplifier without upsetting the operation or picking up hum, so that the arrangement may be found to be of considerable convenience. Alternatively, of course, the control may be built into the amplifier circuit in the normal way. The operation is somewhat complicated to explain as the bass and treble controls have a reflected effect on each other, but the overall result is a very flexible and smooth control system, and, within reasonable limits, the exact shade of compensation can be achieved to suit the individual acoustic taste.

### "HIGH FIDELITY" REQUIREMENTS

Good as the above circuit is, it may not be sufficient to give full satisfaction to "high fidelity" enthusiasts. High fidelity in its fullest sense means having reproduction as nearly like the original as possible and therefore includes the very low notes as well as the extreme high range of audio frequencies and should, therefore, include all frequencies from 16 c/s. to 20,000 c/s. But above this there are many super-sonic harmonics which assist in giving instruments their individual "timbre." Luckily the ear is a very accommodating instrument and tends to fill in deficiencies automatically, so that in practice "high fidelity" is coming to mean a reproduction with a top limit of some 15,000 c/s. It is often of great assistance to have two speakers in the output stage, one for the bass, middle tones, and lower range of the higher frequencies, and, in phase with it, a small speaker designed specially for the reproduction of the high audio frequencies. The second speaker may be of the P.M. type with a 4 or 5 inch cone of shallow con-

struction. The output stage can then be coupled up as shown in Fig. 12.

To feed such a stage efficiently we require to have a wide range tone control system, especially if the amplifier is to be used for low volume level reproduction. We have already mentioned that the ear is less sensitive to very low and very high audio frequencies at low volume, and that it is only the middle range that has a linear response with change in volume.

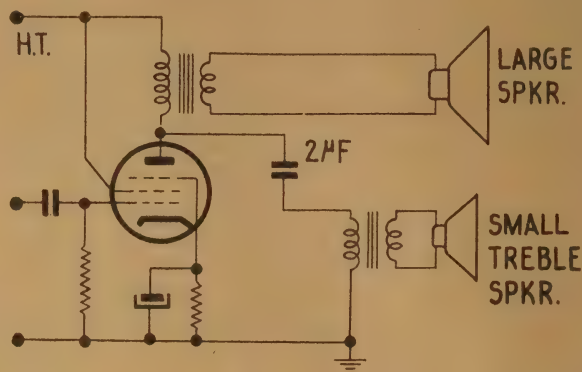
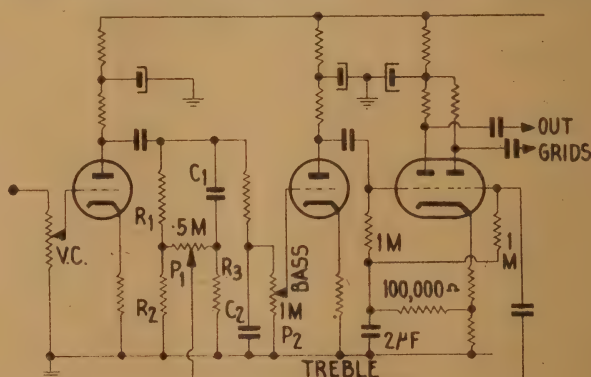
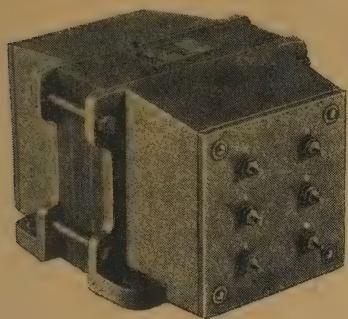


Fig. 12.

Requirements for good reproduction and pleasant tone are, then, to have a very great lift of the extreme bass and a reasonably large lift of the extreme top. This implies that the bass should have a separate amplifier, and as its output will be in anti-phase with the output of the first amplifier, the two outputs can be fed direct to the grids of a double triode and thence to the push-pull final stage. Such an arrangement is shown in Fig. 13 in which a magnetic pick-up is assumed. If a crystal pick-up is used suitable modification of the input circuit can be made as shown in Fig. 10 (B). It will be noted that





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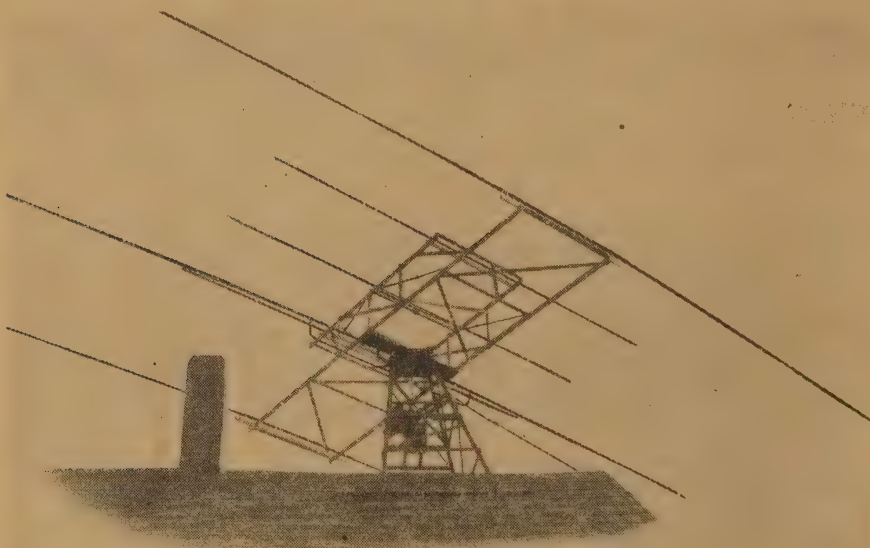
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# A DOUBLE 10 and 20 METRE BEAM\*

By K. L. KLIPPEL, W9SQO, Collins Radio Company.

One quick swing across the ham bands is all that is needed to convince one that post-war amateur activity has hit a new high. This, of course, means a great deal of QRM on all bands. While there is no magic method of eliminating it, there are a number of things that one may do to obtain successful QSO's. The use of a good receiver helps immeasurably. A correctly adjusted speech clipper helps no end, but the best single item is a high-gain, uni-directional antenna system. In addition to boosting your own signal in one direction, you avoid QRMing stations in other directions. It has been found and accepted in general that the multi-element parasitic beam antenna probably offers the best all around solution. Its gain is reasonable, space requirements low, and it may be rotated to radiate and receive in any direction.



After successful operation at W9SQO with a three element rotary beam on 10 metres, it was decided to build a new beam for both 20 and 10 metres as these two bands together offer more excitement in the way of DX and other unusual contacts. For ease of operation it was decided to use a reversible A.C. motor to rotate the beam and to use surplus Selsyns for indicators. First, the electrical details had to be worked out. Since previous experience with most all types of feed indicated that the so-called "T Match" was by far the most satisfactory, this method was used throughout. The system is quite similar in theory to the well-known "Delta Match." However, it offers advantages not found in the Delta Match System. It is possible to obtain a very low standing wave ratio utilising the "T Match" and, in addition, there is no radiation from the matching section. A further advantage of this system over most is that it is for all practical purposes not frequency conscious. Abhorrence of extra labour led to the purchase of some Amphenol 300-ohm line for a feed system.

Since both 10 and 20 metre operation was desired, an investigation of several systems for two-band antennas was made. All systems examined had undesirable features so it was decided to make two beams and stack one above the other. Shortage of lumber necessitated shorter reflector spacing than usual on the 20 metre beam, but no ill effects were

noted as the beam is not extremely frequency conscious.

The best compromise between gain and size for the 20 metre band seemed to indicate that one driven element, one parasitic director, and one parasitic reflector be used. The basic electrical layout for both the 10 and 20 metre beams is shown in Fig. 1.

The 8 in. dimension is not too critical but should be within 1 in. The 3 ft. 5 in. dimension should work satisfactorily as is, but should standing waves be noted on the transmission line, this dimension should be varied until the standing waves disappear.

(It is admitted that the 10 metre beam should

have been a four-element array as use of the "T Match" eliminates the problem of the very low radiation resistance encountered in four-element arrays, making conventional feed methods inefficient. However, three elements were on hand from a previous beam so they were used. The electrical layout before tuning is identical with the 20 metre beam. The dimensions for the matching section are shown in Fig. 1C.

The 10 metre beam is mounted to fit above the 20 metre beam and radiate in the same direction. At first it was feared that there would be interaction of the two due to the proximity, but tests indicate that there is none whatsoever.

Both antennas are fed with Amphenol 300-ohm line. By now the characteristics of this line are well known to most amateurs. Since the surge impedance varies considerably during rain, some method must be used to eliminate this. After examination of the properties of many compounds, it was decided to use Dow Corning Compound No. 7. This compound apparently leaves the characteristics of the line unchanged during normal operation and during rain very small line variations are noted. The compound resembles a jelly and is applied with a rag. A thin, even coat is all that is required. Other compounds may be used but care should be taken that the use of them does not change the 300-ohm characteristic

\*While there are many references in this article to products unobtainable in this country, this hardly impairs the value of the story to would-be builders of rotary beams, as substitute materials can always be improvised.—Ed.

impedance of the line. A D.P.D.T. switch is connected to both feeders in the operating position so that the transmitter output may be switched to the desired antenna. The transmitter is coupled to the antenna directly from a three-turn variable coupling link.

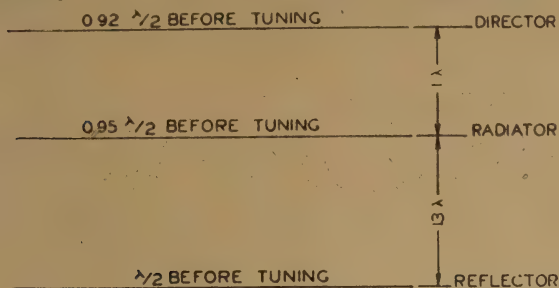


FIGURE 1A

T-MATCHING SECTION - 20 METERS

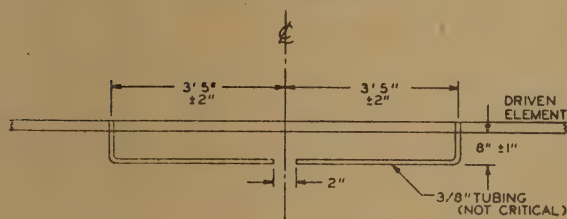


FIGURE 1B

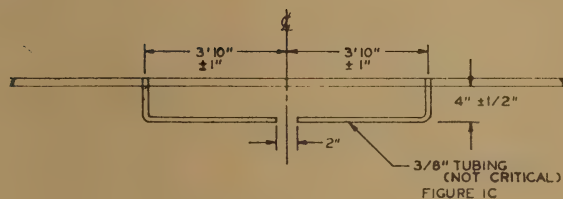


FIGURE 1C

This system of feed will allow efficient use of slip rings if desired. At 300 ohms input resistance with 300 watts of R.F. power being fed to the antenna, the feeder current will obviously be one ampere. If a 30-ohm system is used the current jumps to 3.16 amperes. Since slip rings or any similar devices are bound to have a certain amount of contact resistance, certain I<sup>2</sup>R loss resistances make themselves known. So if slip rings are used, one should be careful to make them rigid and tight fitting. If this is done and the 300-ohm "T Match" system of feed is used, losses are negligible. Since a reversible A.C. motor was on hand it was decided to feed directly with a flexible line and use a "stop" on the array to prevent feeder tangling.

As would be expected, the mechanical problems involved in this system are somewhat more complicated than the electrical problems. Procurement of elements is quite difficult. It is a well-known fact that the larger diameter elements are more desirable, both electrically and mechanically. Thin-wall steel conduit was used for the 10 metre beam elements as shown in Fig. 2.

All three elements were constructed in the same manner (Fig. 3). The ends of the circular piece

were notched out 6 in. back and then clamped tight on the telescoping ends after the system had been tuned. After tuning, all elements should be coated with shellac and corks placed in the ends to prevent rusting. All elements on both beams are mounted on

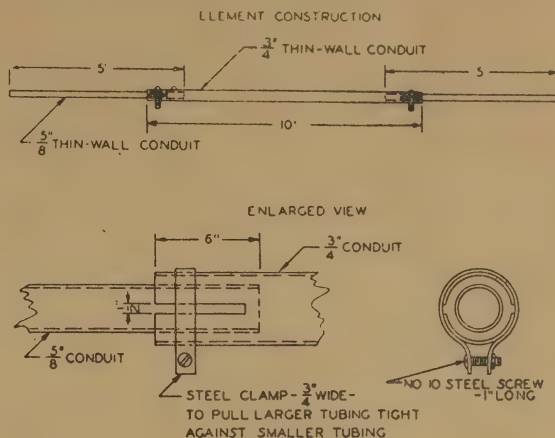


FIGURE 2

metal base standoff insulators, being secured to these by fuse clips with a small retaining wire. This enables one to put the beam structure on the tower without bothersome interference by dangling elements. The elements are then put in place after the structure has been mounted on the tower. The centre section of the 20 metre elements was constructed in exactly the same manner as the 10 metre elements. Obviously, if one wishes to avoid supporting the elements very far out, lighter material than steel

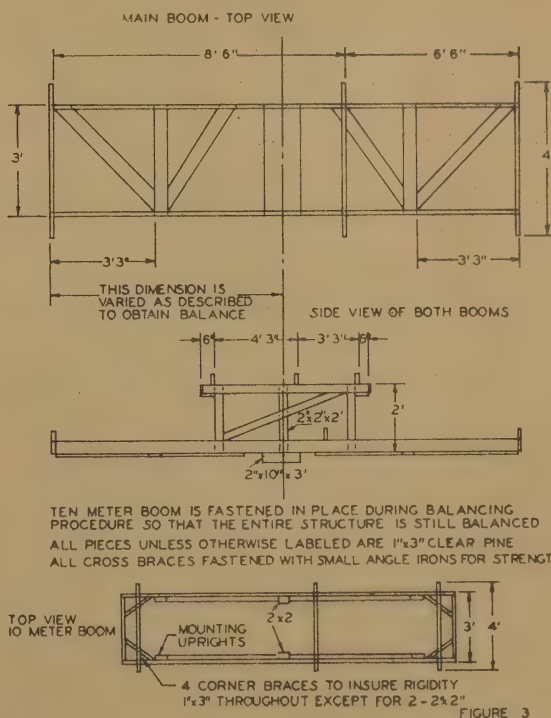


FIGURE 3

must be used for the end pieces. Half-inch duraluminum tubing was purchased from the Allied Radio Corporation for this purpose. Then all elements are tuned by varying the lengths of either side of the fixed 10 ft. centre piece. Both sets of beam elements

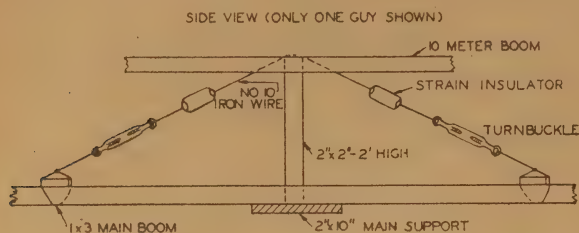


FIGURE 4

have only 4 ft. of support. End sag on the large beam is approximately 1 ft. Support is given the boom by guy wires that are kept tight by turnbuckles as shown in Fig. 4.

As was shown in Fig. 3, the entire boom rests on a single 2 x 10, 3 ft. long. A pair of greased pipe flanges are used for bearings and the 1 in. pipe extends down into the tower to connect with the rotating assembly. It is extremely important that this entire structure be well balanced. The best way of accomplishing this is on the ground with all elements in place and everything on but the 2 x 10. Balance the boom on a sawhorse and then fasten the 2 x 10 support in the centre. This secures balance in the

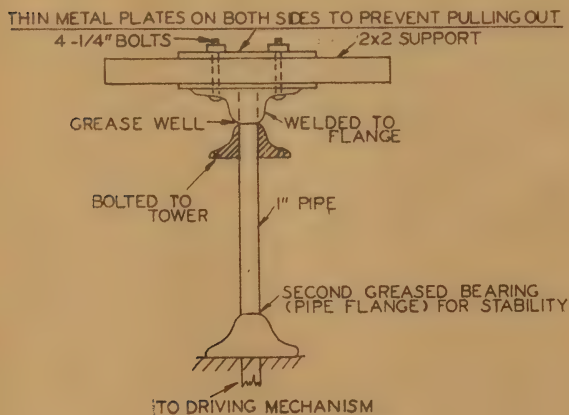


FIGURE 5

long dimension of the boom. To obtain balance in the short dimension, rest the entire system on a vertical pipe, again checking for balance. Then mark the exact centre of balance and secure the supporting pipe to the 2 x 10 at this point. This was done by welding a flange to the pipe, then bolting the flange to the 2 x 10 support. The bearing and support system is shown in Fig. 5.

The system is driven by a small reversible A.C. motor delivering 50 in. pounds of torque at 1 1/2 r.p.m. Construction of a gear drive mechanism will vary in almost every case so we will pass over it but say again that with the bearing surface described and supporting structure described, 50 in. pounds of torque at 1 1/2 r.p.m. will drive the beam nicely.

Indication of direction is of paramount importance for ease of operation. A very inexpensive manner of accomplishing this is by use of self-synchronous motors, more commonly called "selsyns." There are a large number of these of all types on the market to-day, but in general are still a bit too expensive. A pair of very satisfactory units was purchased from the Collins Radio Company for the very modest price of \$5.00. These were not designed for 60-cycle operation so a method had to be devised to make them perform on 60 cycles. It was found that the rotor voltage could not exceed 30 volts or excessive heating would result. As no 30-volt transformer was readily available, another system was used. The rotors were connected in series with a 40-60-watt lamp connected in series with the two. The lamp does not light to full brilliance but just enough to be very useful in illuminating the indicator map. A polar projection of the earth, centred on the United States, is placed at the operating position with a selsyn behind it. The pointer extends through the map and when coupled to the selsyn shaft indicated where the beam is pointed at all times. Fig. 6 shows the electrical connections of the system.

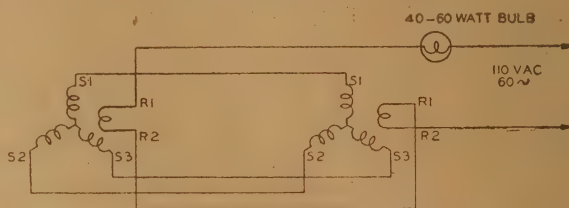


FIGURE 6

It is imperative that extreme care be used in the tuning of both beams. Enough has been written so that most amateurs know the basic system involved, so we will only hit the high spots. The first tuning attempt was made using a field strength meter about 200 feet distant. Results were poor and apparently the tuning was not at all critical. Since an array of this type is inherently critical it was decided to tune it through co-operation of another station about one mile away. With the reflector set at  $\lambda/2$ , radiator at .95  $\lambda/2$  and the director at .92  $\lambda/2$ , the beam was rotated so that the receiving station was directly off the back. Then element lengths were varied until the R meter reading on the receiving station end was at a minimum. This, of course, means tuning for maximum front to back ratio which is very useful in receiving. A slight increase in power gain may be realised by putting the beam right on the station and tuning for maximum R meter reading. There is very small loss in forward gain when tuning for maximum front to back but it appeared to be the best way as "off the back" QRM is minimised.

It is impossible to read gains and front to back ratios on a field strength meter or on a local receiver because they can only give ground wave readings. However, these were surprisingly close. A number of tests were made at distances of around 1,500 miles and a fairly good average of the front to back ratios found is 24 db.

Protection against lightning is a rather simple task. Since the centres of all elements are at zero R.F. potential they may be connected together and

(Continued on page 48.)

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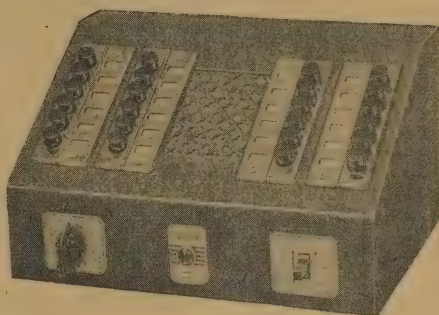
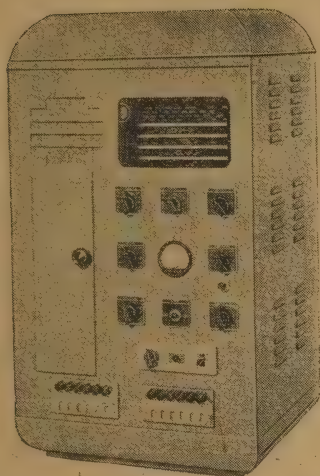
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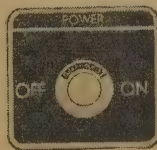
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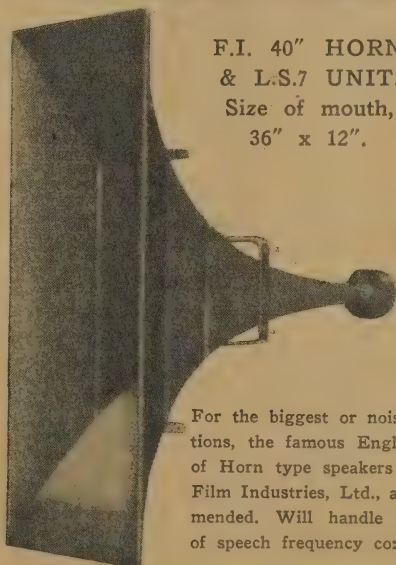


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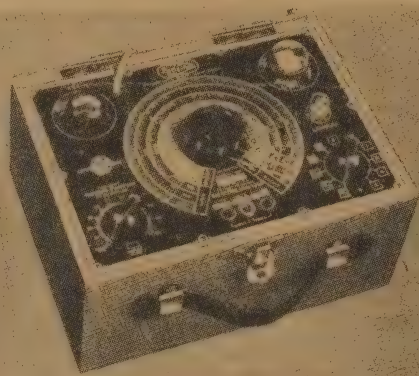
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# The Design of Iron-Cored Solenoids

This subject may not at first sight have very much to do with radio or any other branch of electronics, but there are many applications in which electronic control operates a solenoid, or in which a solenoid is used to control other circuits. This article answers some of the pertinent questions, such as "How may a solenoid be wound to have a particular pull?" or "How must the coil and plunger be designed to give a certain travel?" or even "How much variation of pull can be expected over the range of movement of the plunger?"

Relays of one sort or another are very often found in electronic equipment, or else can be used with advantage in the control of such gear. It is possible to buy almost any desired type of relay, either D.C. or A.C., but solenoids, which can be used to translate an electrical signal into mechanical movement, are not so easily come by. In addition, the solenoid can be used as the basis of home-made relays, if commercial relays are found to be too expensive. The main difficulty about making a suitable solenoid for a given job is not one of construction, but rather is it a matter of being able to fix on a design which will give the required pull, in which the operating current must not exceed a certain amount, where the plunger movement is required to be so much, or where the pull must not vary by more than a certain amount. There is a considerable dearth of information of this sort in the books likely to be found in the average radio worker's library, with the result that much time is wasted in designing solenoids by the "cut-and-try" method, and in many cases a project is carried out by using some other scheme not really so simple or so suitable. The material in this article has been obtained mostly from "Electric Relays," by J. Rosslyn, and published by George Newnes, Ltd., London. If further information is required on any point in connection with solenoids, or on any type of relay, the reader would be well advised to consult this excellent volume.

## DEFINITION

The term "solenoid" used in this article represents a specialized use of the word, and refers to the solenoid coil, usually with a length/diameter ratio much greater than unity, complete with its iron core, which is so arranged that when a current is passed through the coil, the core is attracted into the coil in such a way that the movement of the core can be made to perform useful mechanical work. This work can take the form of closing some electrical contacts, in which case the whole device is a form of relay, or it can entail any mechanical process whatever. The solenoid can operate the control surfaces of a model aircraft, operate a counter, work a push-button type of mechanism for tuning a receiver, cause a wheel to move through a certain fraction of a turn, by means of a pawl and ratchet, or do any one of a hundred other jobs involving the control of a mechanical action by an electric current.

## MAIN REQUIREMENTS

The two main factors governing the design of a solenoid for a particular application are, first, the pull needed, and secondly, the length of travel over which this pull must be maintained. A large number of factors control the pull obtained from a given solenoid. They are:—

- (1) The ampere-turns of the coil.
- (2) The area of the plunger.
- (3) The magnetic material from which the plunger is made.

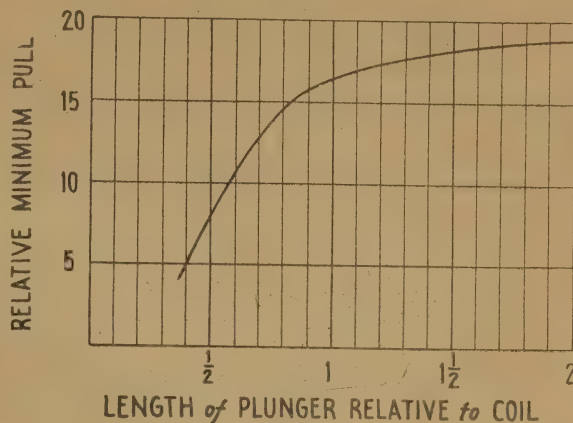


Fig. 1.

- (4) The position of the plunger with respect to the coil.
- (5) The length of the coil.
- (6) The length of the plunger relative to that of the coil.

## LENGTH OF PLUNGER

The length of the plunger is determined by three things: The pull required, the stroke or travel, and the permissible variation in pull as the plunger moves over its travel.

From the point of view of obtaining as much pull as possible, the plunger should be long compared with the coil. The space taken by the whole arrangement is often a consideration, and this tends to prevent a very long plunger from being used. The curve in Fig. 1 shows how the relative lengths of coil and plunger affect the pull obtained. It will be seen that the maximum pull given by a particular coil, with a given current flowing in it, depends very greatly on the length of the plunger. The shape of this curve is important, as it shows that for plungers shorter than the coil the pull falls off quite rapidly, but that for plungers longer than this the pull increases only slowly as the length is increased. Thus, it would hardly ever be worth while making the plunger more than one and a half times the length of the coil, while, unless the utmost efficiency is needed, a plunger the same length as the coil will often be satisfactory.

However, the factor which has most influence on the length of the plunger needed is the stroke, in conjunction with the permissible variation in pull. It can be taken that, except in special circumstances, the pull is required to be as constant as possible. This being the case, a good working rule is that **THE PLUNGER SHOULD BE NOT LESS THAN THREE TIMES THE LENGTH OF THE STROKE**. If this condition is satisfied, the pull will not vary by more than 15 per cent. over the whole

movement of the plunger.

Since the stroke required is determined by the mechanical considerations, and not at all by electrical ones, the determination of this feature is the first step in the design of any solenoid. Once decided, this in turn fixes the length of the plunger, which in turn decides the length of the coil. These are two important quantities fixed. For example, suppose the solenoid has to operate a pair of contacts whose spacing is  $\frac{1}{4}$  in. The plunger must then be  $\frac{1}{4}$  in. long. Also, if the current consumption of the coil must be as low as possible, the coil should be  $\frac{1}{2}$  in. long.

#### POSITION OF GREATEST PULL

Where it is important to get the greatest possible pull, it is important also to know at what position of the core relative to the coil maximum pull occurs. The rule to be followed is that the longer the plunger, the farther into the coil is the position of

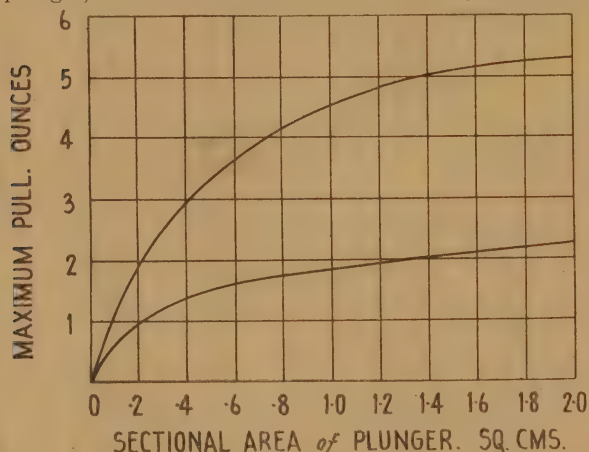


Fig. 2.

the greatest pull. For plungers of one and a half times the coil length, or longer, maximum pull occurs when the length of the plunger inside the coil equals two-thirds the coil length. If the plunger is allowed to travel far enough, so that the coil is over the centre of the plunger, equilibrium is established, and, of course, the pull vanishes, even if the current is still on. It is this fact, combined with the above statement of the position of maximum pull that determines that the best length for the plunger is three times the required stroke.

#### AREA OF PLUNGER

The cross-sectional area, and therefore the diameter of the plunger, is the only dimension that has yet to be fixed in order to settle the design of the plunger. The pull increases as the diameter of the plunger is increased, but the variation is a function also of the magnetizing force of the coil. This is illustrated in Fig. 3, which brings to light a number of points. First, for small coils of comparatively few ampere turns, increasing the area of the plunger does not increase the pull so rapidly as when a larger magnetizing force is employed. Secondly, for small-diameter plungers, the pull is not proportional to the number of ampere turns in the coil. Doubling the magnetizing force more than doubles the pull when the plunger is narrow, whereas when it is wide, the pull increases in proportion to the magnetizing force.

A useful table is given below in which the diam-

eter of the plunger is given as a function of the required pull.

Max. pull ounces	Diam. of plunger inches
2	7/16
4	5/8
6	3/4
8	7/8
10	1
12	1 1/8
14	1 1/4
16	1 1/2

#### MAGNETIZING FORCE

It is difficult to make accurate calculations of the magnetizing force required to give a specific pull, but experience has shown that an allowance of 250 ampere-turns per ounce pull is adequate, without being wasteful. Fig. 3 illustrates the manner in which the pull varies for a given core and plunger, when the number of ampere-turns is varied. For the widest plunger, the relation is almost linear for anything over 1000 ampere-turns. The lower curve is interesting, as it shows that for small plungers there is a point after which increasing the magnetic flux makes little difference to the pull. This represents saturation of the iron of the plunger, and does not show up on the curves for the larger plungers because the maximum flux is not great enough.

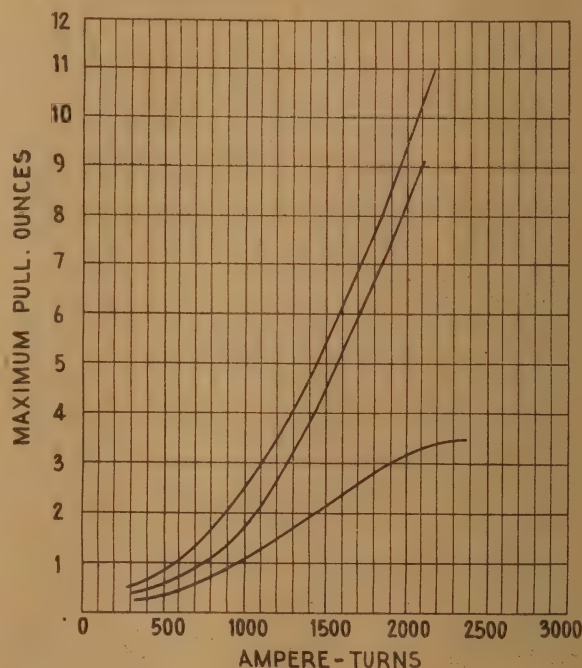


Fig. 3.

Fig. 3 is simply an illustration of the kind of behaviour that can be expected, and refers to only one particular solenoid. However, the rule given above is accurate enough for all practical purposes. For instance, if a pull of 2 oz. is wanted, 500 ampere-turns will be needed on the coil. The length and diameter of the coil former are determined by the dimensions of the plunger, which have already been decided from the available data. Thus, all that remains to be done is to make the end plates of

the bobbin of sufficient diameter for 500 ampere-turns to be wound on. Thus, if the available current to produce the flux is 0.1 amp., 5000 turns will have to be put on the bobbin. The rest of the coil design is merely a matter of choosing a gauge of wire that will pass the required current and making the bobbin large enough to get the turns on.

### SUMMARY OF DESIGN PROCEDURE

By way of summarizing the information set out above, we will detail the steps necessary in designing a given solenoid and its associated plunger.

- (1) Determine from the mechanical requirements the desired stroke.
- (2) Fix the plunger length as three times the stroke.
- (3) Fix the diameter of the plunger from the above table, knowing the maximum pull needed.
- (4) Fix the length of the solenoid as two-thirds the length of the plunger or, what is the same thing, twice the stroke.
- (5) Find the required number of ampere-turns for the coil by allowing 250 ampere-turns per ounce pull.
- (6) From the wire tables find the gauge of wire necessary to carry the current, which can be the maximum available from the battery or other source of power from which the coil is to be operated.
- (7) The bobbin diameter is now made large

enough to accommodate the required number of turns, which can be worked out from the relation that number of turns = number of ampere-turns ÷ solenoid current.

This procedure is very easy to carry out, but there are one or two points that need to be watched in case the coil does not turn out to be practical in design. For example, if too many layers of wire have to be wound on to the bobbin, the latter becomes too great in diameter. This causes the magnetic flux to be less than is expected from the number of ampere-turns used. The cure is to make the solenoid longer than twice the stroke, which results in more turns of wire per layer, and therefore in fewer layers. An estimate of the finished diameter of the coil can be made after the paper design is finished, because the total number of turns is then known, the length of the coil is known, and the wire size is also known. Thus, the number of turns per layer can be worked out, after which the required number of layers can be found. If an allowance is made for the thickness of the paper insulation between layers, one can thus obtain a good idea of the diameter of the finished solenoid, and therefore of whether it is necessary to increase the length of the coil. Of course, this may have to be done in any case, purely from the necessity to conserve space. Alternatively, if space is at a premium in the direction of the stroke, it may be necessary to use a coil shorter than recommended and put up with a little more variation of pull over the stroke.



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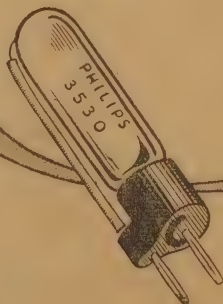
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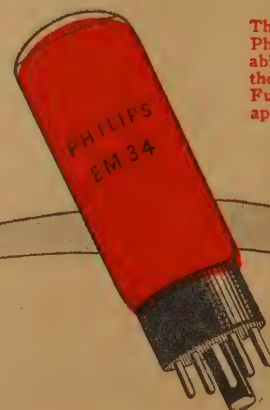
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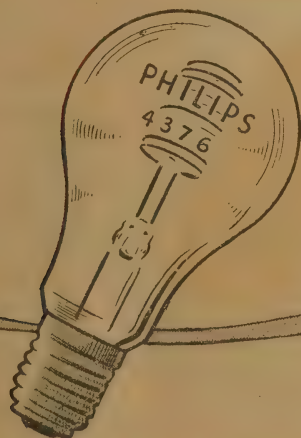
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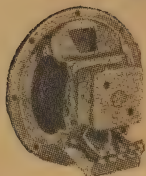
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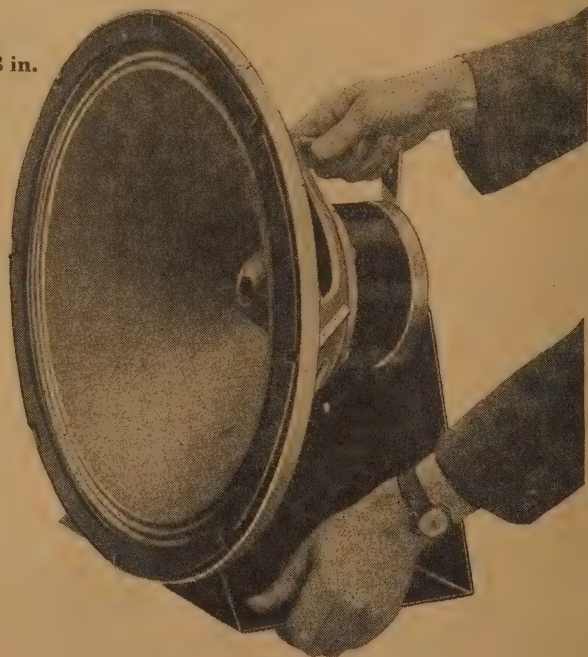
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# SERVICING HINT ON FAULTS IN DUAL-WAVE COIL INSULATION

By E. C. WATKINS.

Due to the demand in recent years for radio receivers of compact design incorporating a fair coverage of the shortwave broadcast bands, manufacturers, and their designers, have achieved noteworthy success in the production of medium-sized radio chassis, operating on the dual-wave principle of two sets of coils wound on either a single former or on separate formers massed in close proximity to the wave-change switch; the coils impregnated with a moisture-resisting compound.

After a reasonable period of performance, these dual-wave coil units can present quite a number of problems to the radio serviceman called upon to repair faults which develop in sets utilizing dual-wave coil assembly, causing indifferent reception. As open-circuits in the continuity of coils are easily traced with an accurate low-reading ohm-meter, and give less trouble to locate, we will confine this short article to faults giving rise to intermittent reception, noise, or complete breakdown between the high-tension primary winding, and the low-voltage secondary, wound in conjunction to it. Open circuits are frequently due to the slow eating away of the finer gauge of wire by corrosion, due to a chemical fault in the wax compound or a minute spot of water; or even the attention of a foraging mouse in search of edible nourishment.

Breakdown in insulation between primary and secondary coils is made by a track of low resistance forming between the two windings, and occurs at times only, sometimes over an interval of days, giving rise to frequent oscillation, sudden drop in signal voltage, and crackling noises; a most unwelcome fault to trace in a busy repair shop. Where the coils are layer-wound one upon the other, the fault can develop in the broadcast section of the coil, but is more often found in the shortwave, or high-frequency section, where a fine primary winding is wound between the turns of a gauge secondary or grid winding. By referring to Fig. A, it can be seen that, even with the wave-change switch in the broadcast position, a fault in the shortwave coil can still affect reception on the other band, because the two low ends are tied together for common use of the automatic volume control system, and that a leak or breakdown from the B1 to the grid winding of one coil affects both coils through this link. The secondary winding being at a low negative potential to the chassis or ground. Note, this is not radio frequency potential.

Where the breakdown is practically complete, the full high-tension voltage will saturate the A.V.C. system and impose a heavy positive bias to the grids and diodes of all tubes in the network, giving rise to no reception, and the frequency changer will pass no signal to the first intermediate stage. If grid current of these tubes is heavy, one unusual feature can be a reading of no volts to the common screen-grid terminal of the receiver. The usual analysis of an open bleeder resistor or a faulty decoupling condenser will not prove correct in this case!

Where the breakdown is a matter of a varying high resistant path, the symptom is crackle, noise,

with varying volume of reception, reoccurring at intervals, oscillation, and double spotting, with a very decided hiss and rise in interference level.

When this trouble develops, the best means of checking is a sensitive voltmeter placed across the A.V.C. terminal of one section of the set. In normal operation, the voltage scale of 10 volts is easiest to read, and will show negative bias on no signal, rising to a peak as a local station or signal from the frequency generator is tuned in. It is this negative

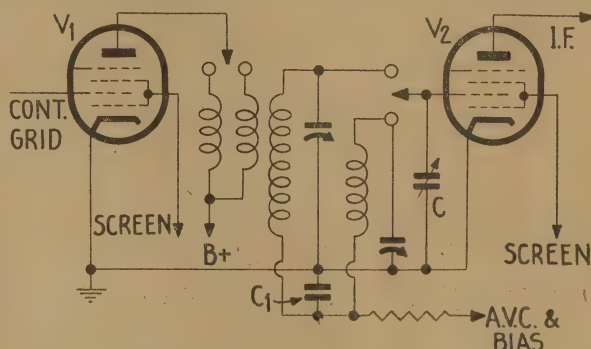


Fig. A. Showing how the common connection between the "earthy" ends of the grid coils allows leakage between primary and secondary of one band to affect the operation of both.

voltage generated by the diodes of the second detector which provides additional voltage for the A.V.C. system and operates the "magic eye," or tuning indicator. As the fault develops, the meter reading will drop and fluctuate or even swing over to a positive reading, giving a visual indication as to which stage the trouble is in. By use of a soldering iron and removing the A.V.C. link to each coil, the fault can be isolated altogether. A more reliable check can be made by removing all R.F. and I.F. tubes from their respective sockets, as these can draw grid current and lower the visual reading on the meter scale. It is as well to mention here that in some overseas commercial models, breakdown occurs in the actual fibres between switch contacts, or in the fibre used as a common mounting for two trimmers used for alignment, but the same method applies in step-by-step servicing.

In some receivers, where the whole dual-wave tuning unit is massed together with the wave-change switch, removal of the offending coil is quite a job, entailing painstaking work and loss of time to the customer. Once the fault has been isolated by routine check with the meter and soldering iron, a very effective and simple repair is available, enabling a fast and lasting repair to be made, with cure of the intermittent fault. The writer has used the repair about to be described with complete success in a large number of cases, and the customer has been very satisfied; and, after all, customer-goodwill is what really counts. Naturally, this repair is not re-

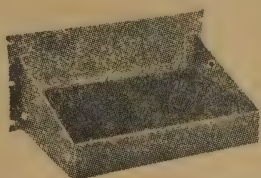




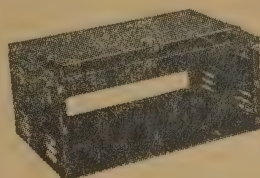
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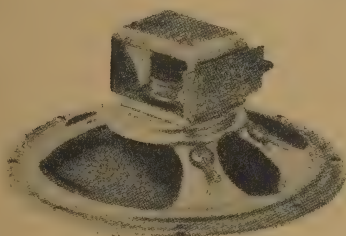
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# THE SYNCHRODYNE RECEIVER AGAIN

Our first two articles on the above system were received with so much interest by our readers that we have obtained special permission from our English contemporary, "Electronic Engineering," to adapt for publication in "Radio and Electronics" two further articles which have been written and published by Dr. D. G. Tucker, Ph.D., A.M.I.E.E., the inventor of the synchrodyne principle.

Since the publication in "Electronic Engineering" in March of last year, of Dr. Tucker's original article on the synchrodyne, so much interest was aroused in England that the author has since published, in the same periodical, a two-part article entitled "The Design of a Synchrodyne Receiver." In Part I of this article is to be found a more extensive description of the synchrodyne principle, embodying a certain amount of mathematical illustration, while Part II presents three practical circuits (complete with component values), all of which have been made to function satisfactorily. One of these is that given by us in our own original article on the subject, while the other two comprise a simplified circuit, using an ECH35 as the synchrodyne detector, and a rather more complex one which is usable on signals as small as ten microvolts. Since the original article, and our own write-up based on it, both created considerable interest in this part of the world, we are sure that readers will welcome some further information of a practical nature, obtained, as it were, straight from the fountain-head.

## RECAPITULATION OF PREVIOUS ARTICLES

For those who may not have seen either Dr. Tucker's original article, or our own previous two, based on it, it would perhaps be as well to indicate briefly what the Synchrodyne is, and what it does.

Briefly, then, it is a new method of receiving amplitude-modulated radio signals, in which the two features of selectivity and fidelity are **not** mutually exclusive, as they most definitely are in ordinary receivers, whether of the T.R.F. or Superheterodyne persuasion. This highly desirable state of affairs is brought about by causing an R.F. oscillator to lock exactly to the carrier frequency of the desired signal. The output of the oscillator and the modulated signal are then passed through a demodulator. In the process, beats are produced between the oscillator and the side-band frequencies. Since each side-band frequency has a value of plus-or-minus some audio frequency from that of the carrier, these beats must also be audio frequencies themselves, and in fact are the original modulation frequencies, so that the output of the detector has only to be passed to an audio amplifier in the ordinary way. If a signal is present on an adjacent channel, the oscillator beats with this to produce frequencies which are all outside the audio frequency range, so that as long as the receiver responds to audio frequencies not higher than 10,000 c./sec., the selectivity to signals on adjacent channels is virtually complete. At the same time, the audio response up to 10 kc./sec. can be as good as may be desired. This can be achieved in practice, because all that is necessary is a low-pass filter which cuts off sharply at the above frequency. Such a filter is readily designed.

From the above it can be seen that the set's selectivity is in no way dependent on the provision of radio-frequency selectivity, either at signal, or at

any intermediate frequency. In fact, it is entirely practical in most circumstances to build a synchrodyne in which the only tuned circuit which works at a radio frequency is that of the oscillator.

## MAIN FEATURES

As pointed out by Dr. Tucker, the features which distinguish the synchrodyne system from other methods of reception are as follows:—

- (1) The separation of the requirements of selectivity and bandwidth, so that each can be determined independently of the other.
- (2) The possibility of omitting all tuning arrangements in the R.F. portion of the circuit.
- (3) The consequent necessity of detecting the combined signal and local oscillator with much less distortion than is encountered in normal detector circuits.
- (4) The synchronization of the local oscillator to the frequency of the desired carrier.

From the above statement, a number of advantages, and also some difficulties follow immediately. In the first place, (1) means that both selectivity and quality of reproduction can be very high. Feature (2) means that there are no difficulties to be encountered due to ganging circuits together at R.F., or to making an oscillator track with them, but at different frequencies. (3) introduces one of the difficulties, in that with no tuning ahead of the detector, any R.F. amplifier stages, and the detector itself, must be extremely "linear," because if they were not, signals from all over the band would be subject to ordinary rectification, and would be heard in the output of the receiver, as "cross-talk." There is a further grave objection to omitting tuning arrangements altogether from the signal circuits, of which no mention is made by Dr. Tucker. When the receiver is tuned to a station near the low-frequency end of the broadcast band, and the local oscillator has appreciable output on its second harmonic, this harmonic is also within the band, so that if there is a strong signal present at a frequency of  $2f$  plus or minus 10 kc./sec., a very strong beat note at 10 kc./sec. will be heard. "f" in this illustration represents the frequency of the desired station. It should perhaps be mentioned that in England, broadcast stations are limited to a channel 10 kc./sec. wide, and therefore to modulation frequencies no higher than 5000 c./sec. Thus the audio filter referred to above can be made to cut off somewhere between 5 and 10 kc./sec., thereby eliminating most possibility of the 10 kc./sec. heterodyne becoming troublesome, and at the same time without losing anything in the way of quality. Feature (4) is the one which has the greatest effect upon the operating characteristics, and upon the technique of constructing such a receiver. The greatest part of the set's selectivity resides in the synchronized oscillator, and its design and adjustment are therefore critical.

## MECHANISM OF DETECTION

If two alternating currents are applied simultaneously to a non-linear circuit element, such as a recti-

fier, the two currents (or voltages, if they are expressed in this form) can be shown to be multiplied together. If the expressions representing the modulated signal and the output of the synchronized oscillator are multiplied in this way, the answer shows that a number of new frequencies appear in the output. All of these are above the audio range except one, which is:—

$$\frac{E_1 E_2}{2} k \cos \theta \sin \omega t$$

where  $\theta$  is the phase angle of the output of the synchronized oscillator with respect to the incoming

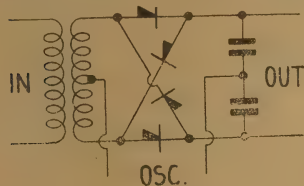


Fig. 2.

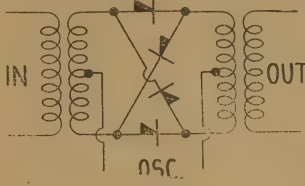


Fig. 1.

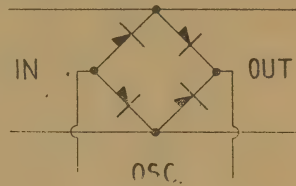


Fig. 3.

carrier, and  $\omega$  is the angular velocity of the modulation,  $k$  is the percentage modulation. This expression shows that the audio output depends upon the relative phase of the carrier and the local oscillator, but that this has no effect on the output waveform. In practice, the output amplitude can vary over a range of about 2:1 according to the exact tuning of the oscillator, but this is not at all serious.

### THE SYNCHRONIZING PROCESS

We know that the local oscillator must be synchronized to the frequency of the desired carrier, but so far nothing has been said about the mechanism used to bring this about. If we are to be able to build a receiver of the kind under discussion, it is necessary to know a little about how synchronization takes place, and in what way the variation of circuit constants affects it. The following outline will perhaps make the matter a little clearer.

Suppose the circuit of the oscillator is so arranged that a portion of the desired signal voltage can be fed in to its grid circuit, and that the oscillator is tuned in such a way that its natural oscillation frequency is very close to that of the injected signal. The circuit under these conditions must have a large amplification to the injected frequency, so that a very small voltage injected into the grid circuit becomes a quite large voltage at the grid of the valve. As in all oscillators, the non-linearity of the valve characteristic prevents the amplitude of oscillation from building up to an unlimited extent. Now if the amplified injected voltage is great enough, it will so reduce the valve's amplification that the natural oscillation (at the frequency of the tuned circuit) can no longer take place, and all that remains is an oscillation at the frequency of the injected voltage. In this condition the oscillator is said to be synchronized, as the output is identical with the control frequency. It can be shown that there are two conditions that must be fulfilled by the injected voltage before synchronization can take place. First, the resultant grid voltage, which is the vector sum of the injected voltage and the amplified injected voltage must be greater than 0.707 times the amplitude of the free-running grid voltage; that is, the grid voltage developed by the oscillator in the absence of the synchronizing voltage. Secondly, the phase of

the injected voltage must not be further than plus or minus 90 degrees from that of the resultant grid voltage. If either of these conditions is not satisfied, synchronization fails.

### PROPERTIES OF THE SYNCHRONIZED OSCILLATOR

When an oscillator is to be synchronized, several important factors have to be taken into consideration. One obvious one is the question of how great a synchronizing voltage is required. The practicability of making a receiver will depend to a large extent on this. Similarly, is the synchronization very critical? What range of oscillator drift can be tolerated if

the synchronism is to be retained for long periods of time? The answers to these questions are to be found in a relationship given by Dr. Tucker and reproduced below:—

$$E_s = 2Q \cdot E_g (f_o - f_s) / f_o$$

In this equation  $E_s$  is the required injection voltage,  $E_g$  is the grid amplitude of the oscillator,  $f_o$  is the natural oscillation frequency of the tuned circuit, and  $f_s$  is the frequency of the injected voltage.

The equation shows, (1) that the required voltage is directly proportional to the amplitude of oscillation. That is, the stronger the oscillation, the more synchronizing voltage is required. (2) That the required voltage is also directly proportional to the relative detuning of the oscillator circuit, and (3) that it is proportional to the  $Q$  of the tuned circuit. Thus, a weak oscillator is easier to lock than a strong one. Also a stable one is more readily locked than an unstable one. This applies only to the use of the term "unstable" to refer to cases where the oscillator frequency will drift due to temperature or other variations which change the values of the circuit components. Obviously a completely stable oscillator in the sense that its frequency cannot be altered by any outside agency would be impossible to synchronize! If the expected degree of fractional frequency variation is known or can be estimated, the above equation provides a ready means of calculating in advance what order of injection voltage will be required, and therefore how much R.F. amplification, if any, will be needed between the aerial and the synch. control. As Dr. Tucker states, a stability of plus or minus 0.1 per cent. should be readily attainable in a well-designed oscillator circuit. When substituted in the equation, this gives a figure of 0.1 volt peak synch. voltage for each volt of oscillator amplitude when the  $Q$  of the tuned circuit is 50. This high value is likely to be realized only when an R.F. pentode is used as the oscillator tube, owing to its high plate impedance. If the  $Q$  is lowered, the required synch. voltage is lowered in proportion, but doing so has an effect on the selectivity of the receiver. It is thus possible to obtain the necessary injection voltage quite easily, as the figure mentioned can be got with relatively little R.F. amplification, even from quite a weak signal in the aerial.

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### TYPES OF DEMODULATOR CIRCUIT

In the synchrodyne, as has been stated, the production of the modulation frequencies is brought about, not by the normal process of rectification, but by the multiplication of the carrier wave, together with its side-bands, by the local oscillator voltage. This takes place in a balance demodulator circuit, in which the output is a linear function of input voltage. This means that if the carrier and side-bands alone were applied to the demodulator, no output at modulation frequency would be apparent, because the carrier is not detected in the ordinary way. If an attempt were made to use a normal detector, such as a half-wave rectifier, not only the wanted signal, but also all the other signals present at the detector input would be rectified, and their modulations would all be present in the output.

In fact, if any part of the whole circuit has a non-linear characteristic (i.e., the output amplitude is not closely proportional to the input amplitude) rectification occurs, with the above undesirable result. For this reason, an ordinary tube of the type used as a mixer in superhet. receivers is not the most satisfactory "mixer" or demodulator in a synchrodyne. The circuit commonly known in this country as the "infinite-impedance mixer" is extremely linear, but would revert to the ordinary infinite impedance detector if an attempt were made to use it. However, with care, an ordinary triode-hexode, such as the ECH35, can be used in a synchrodyne circuit, as shown in Fig. 5.

For best results, Dr. Tucker advises the use of a ring-type demodulator circuit, using either four crystal rectifiers such as the 1N34, or else four diode valves. In some cases the audio output voltage is so small that the latter cause trouble with hum, derived from their heater circuit. The basic circuit of the ring demodulator is given in Fig. 1. It is essentially a balanced affair, and works between transformers, the oscillator voltage being injected between the centre-taps.  $T_1$  is of course an R.F. transformer, while  $T_2$  is an audio transformer. It is possible to do away with the latter by using the scheme shown in Fig. 2, where the output is centre-tapped by means of two equal condensers. These must have a low reactance at R.F. but a high one at audio frequency, so that the latter is not bypassed to earth. A disadvantage of this scheme is that it provides balanced output, which would require an audio amplifier which is push-pull in all stages. An alternative circuit, still using four rectifiers, is the Cowan circuit, shown in Fig. 3. This was the one used in the circuit of our previous article. It has the disadvantage of being slightly less efficient than the ring circuit, and that the oscillator voltage needs to be twice that required by the latter.

### OSCILLATOR REQUIREMENTS

The output voltage required from the locked oscillator is not very great, as all it has to do is to switch the rectifiers from fully conducting to fully non-conducting. With the ring circuit only about one volt peak is needed. With the Cowan circuit, approximately twice this voltage is required. If a triode-hexode is used, an oscillator output (i.e., at the osc. grid) of 10 volts or so is required for proper operation. This is readily obtained with conventional circuits, but necessitates in its turn a large synchronizing voltage of between 0.5 and 1.0 volts. This introduces a little difficulty in respect of linearity if the full available R.F. voltage is applied to the signal

grid, so that it may be advisable to attenuate this by means of a pad or potentiometer.

### ACTUAL CIRCUITS

Fig. 4 is identical with the illustrative circuit used in our initial article. It is a low-sensitivity circuit which works well with signals of about 50 millivolts. Its audio output is very low, being of the order of 1 mV. for an input signal of 50 mV. If desired, the sensitivity can be increased by adding an R.F. stage such as the one illustrated in Fig. 5. This will enable signals of about 2 mV. to be received.

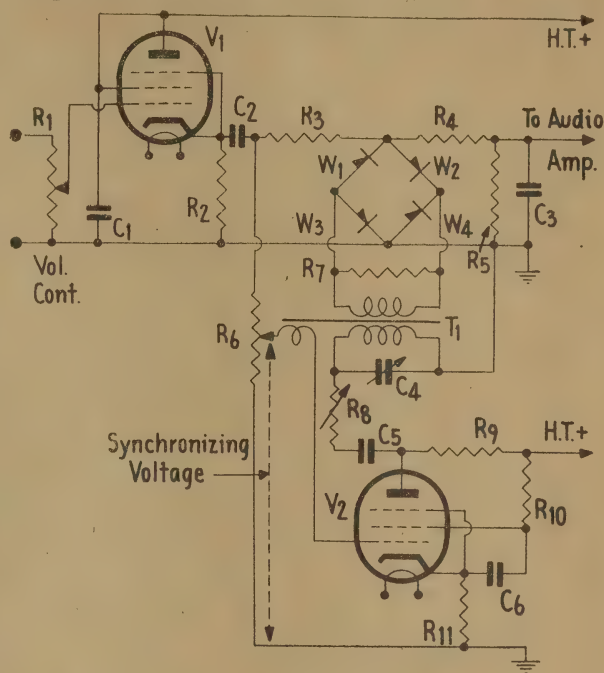


Fig. 4.

- |  |   |
|--|---|
| $R_1$ , not critical, say 1,000 ohm pot. | $C_1, C_2, C_5, C_6$ , 0.05 mfd. not critical.    |
| $R_2$ , 300 ohms.                        | $C_3$ , 0.005 mfd.                                |
| $R_3$ , 5k.                              | $C_4$ , 500 mmfd. variable.                       |
| $R_4, R_5$ , 2,500 ohms.                 | $W_1 - W_4$ , 1N34 crystal rectifiers or 2 6H6's. |
| $R_6$ , 10k. pot.                        | $T_1$ —   |
| $R_7$ , 250 ohms.                        | Tuned winding, 100 $\mu$ H.                       |
| $R_8$ , 250k. variable.                  | Grid winding, 10 $\mu$ H.                         |
| $R_9$ , 10k.                             | Output winding, 1 $\mu$ H.                        |
| $R_{10}$ , 20k.                          | $V_1, V_2$ , EF50, 6AC7 or similar tubes.         |
| $R_{11}$ , 200 ohms.                     |   |

In the circuit of Fig. 4,  $R_8$  controls the amplitude of oscillation, while  $R_6$  determines the signal voltage fed to the grid of the oscillator to effect locking.  $R_8$  should be adjusted so as to develop about 2V. across  $R_7$ . The control  $R_6$  should be set at maximum if only weak signals are received, but for signals over about 100 mV. a lower setting should be used. If at any time the discrimination against unwanted signals is not good enough, it may be improved by using a lower setting of  $R_6$ .

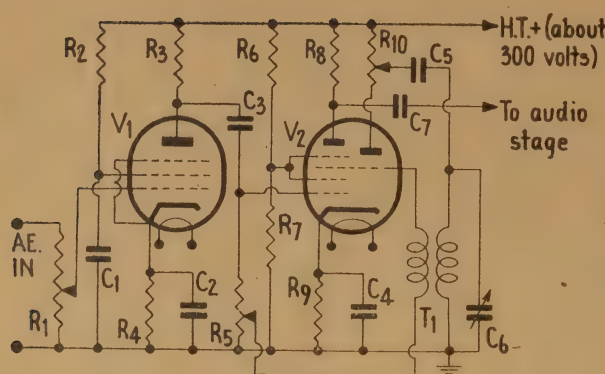


Fig. 5.

- $R_1$ , not critical, say 1,000 ohm pot.  
 $R_2, R_7, 30k.$   
 $R_3, R_8, 10k.$   
 $R_4, 300$  ohms.  
 $R_5, 10k.$  pot.  
 $R_6, 25k.$   
 $R_9, 200$  ohms.  
 $R_{10}, 10k.$  pot.  
 $C_1, C_3, C_5, 0.05$  mfd., not critical.  
 $C_2, C_4, 0.1$  mfd., not critical.  
 $C_6, 500$  mmfd. variable.  
 $C_7, 0.1$  mfd.  
 $V_1, EF50, 6AC7$ , or similar.  
 $V_2, ECH35.$   
 $T_1$ —  
 Tuned winding,  $100 \mu H.$   
 Grid winding,  $10 \mu H.$

In his latest article, Dr. Tucker states that the low-pass filter specified in his original article is not always required, because the audio amplifier does not pass frequencies much higher than the audio range in any case. This is quite true, but as he again points out, omitting the filter may cause trouble through non-linearity in the audio amplifier acting as a detector of the supersonic unwanted output frequencies.

### GREATEST SIMPLICITY

Fig. 5 is Dr. Tucker's circuit for the simplest possible synchrodyne. It can receive signals down to about 10 mV., and at that input gives an audio output of approximately 1 volt.  $R_{10}$  must be adjusted to give an oscillator amplitude of 7 to 10 volts at the oscillator grid when there is no input signal.

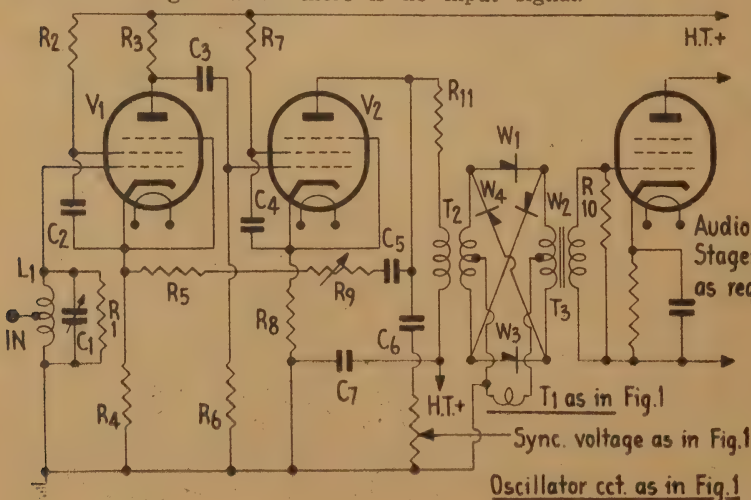


Fig. 6.

- $R_1$ , not critical, say 1,000 ohm pot.  
 $R_2, 10k.$   
 $R_3, 20k.$   
 $R_4, 200$  ohms.  
 $R_5, 100k.$   
 $C_1, C_2, EF50, 6AC7$ , or similar.

$R_5$  is the synchronization control. The input potentiometer should be adjusted so as to give about 0.3 to 0.5 volt across  $R_5$ .

### HIGH SENSITIVITY

Fig. 7 is the circuit of a high sensitivity receiver which will work on signals as small as 10 microvolts. It uses the ring type demodulator, and the same oscillator arrangements as the circuit of Fig. 4. It uses a two-stage R.F. amplifier, and the input circuit is tuned and ganged with the oscillator. This is necessary in the high-gain receiver in order to keep down the amplitude of strong unwanted signals when a weak one is being received. Negative feedback is used over both stages of the R.F. amplifier, in order to achieve good linearity. In addition, the feedback resistor  $R_9$  is used as a volume control.

(Continued on page 48.)

Fig. 7.

- $R_1$ , damping resistor, required only if input circuit is too selective.  
 $R_2, R_7, 20k.$   
 $R_3, R_5, 10k.$   
 $R_4, R_8, 200$  ohms.  
 $R_6, 100k.$   
 $R_9$ , vol. control, 250k.  
 $R_{10}, 200k.$   
 $R_{11}, 5k.$   
 $C_1, 500$  mmfd. variable, ganged to osc. condenser.  
 $C_2$  to  $C_7$  inc., 0.05 mfd., not critical.  
 $L_1, 100 \mu H.$ , centre-tapped.  
 $W_1 - W_4$ , as before.  
 $T_2$ , iron-cored—  
 Plate winding, 7 mH.  
 Sec. winding, 1 mH., centre-tapped, turns ratio 2.5:1.  
 $T_3$ , any good quality audio transformer step-up about 1:10 Primary in two balanced halves, inductance about 10H.



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## PART 19

### BUILDING A SHORTWAVE SET

Armed with this information, we are now in a position to see if we cannot build a set that will bring in some shortwave stations. The circuit we will use is that of Fig. 28 exactly.

The lay-out of parts can be the same as before, and all we will change is the coil. This enables us to build a shortwave set of a sort without any further expenditure for parts, which is a worth-while consideration. However, we will alter the mechanical set-up a little, in order to make our next experiments a little easier.

First, the broadcast coil is disconnected from the set and is unscrewed from the base-board. The shortwave coils we are about to make will be wound on the bases of discarded valves, which make excellent formers that can be plugged in and out of the set at will. This is made possible by mounting a valve-socket on the base-board of the set and wiring the circuit to four of the contact pins instead of

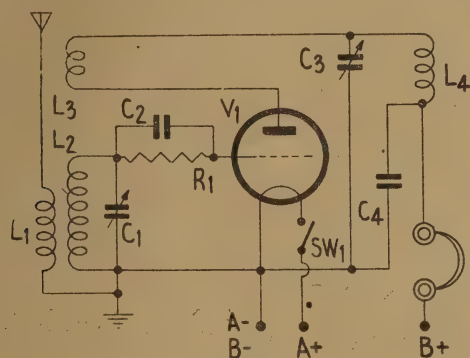


Fig. 28.

directly to the wires of the coil, as was done with the broadcast set. Then the wires from the coil are terminated by soldering them to the pins of the old valve-base on which it is wound. The set is then completed simply by plugging the coil into the socket that has been wired into the set. The idea of all this is that to cover the great range of frequencies that make up the shortwave band, several coils are needed, and some such arrangement is necessary if we are to avoid having to unsolder the wires to a coil every time we want to tune the set to a frequency that is not on the coil in use at the moment. Commercially-made sets at one time used a system of plug-in coils in order to provide different wavebands, but manufacturers have almost all discontinued the practice, because the public object to the inconvenience of it. Instead, practically all commercial sets now use what is called "band switching." In this arrangement, a set has a set of coils for each band to be covered, and a switch is turned which puts one set of coils out of commission and automatically brings another set into use. This is all very nice for a permanent job, but for an experimental one, where changes are being made all the time, it has no advantages, and is a

good deal more costly and complicated to build. For some purposes, it is also much less efficient.

A glance at our circuit, Fig. 28, shows that if we are to use the plug-in system we must have a coil former and valve-socket with at least five connections. Although there are three windings on each coil, only five pins are needed, because two coil ends are connected to the same point on the circuit. However, a six-pin base and socket is the best to use, because then each coil end has its own pin on the former and the coil is easier to construct. The two pins that are earthed in the circuit are then connected together and earthed at the coil socket.

### MAKING A SHORTWAVE COIL

Shortwave coils are really much easier to make than broadcast ones, since in general they have much fewer turns than the latter. First, we must obtain a number of old six-pin valves, of the types which have the large base, about 1½ in. in diameter. The next step is to remove the bases. This is most easily done by breaking the glass envelope of the valve and cutting off the wires that go through the glass to the pins, as far as possible from the base. The remaining bits of glass and cement are scraped from inside the base. Finally, by way of preparation, the wires which lead into the valve pins are unsoldered and pulled out from the pins while the solder is still liquid. The best way to do this is to hold the base in the right hand, at the same time gripping one of the wires with a pair of pliers, also held in the same hand. Then the pin corresponding

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to the wire that is being held is applied to the soldering iron. When the solder has melted, a pull on the pliers will remove the wire. Since we have later to solder new wires to the pin, it is helpful to remove as much solder as possible from the pin, leaving a clear hole through which the new wire can be threaded. To do this, heat the pin once more until it is hot enough for the solder to stay melted for a little while after the iron has been removed, and then, before it has solidified again, blow sharply through the base, holding it right in the mouth for the purpose. This leave a perfectly clear hole in the pin and no jagged bits of solder inside it to hold up the passage of the wire when it is being threaded through.

When all the pins have been treated thus, the former is ready for the coil to be wound. In doing this, Fig. 29 will be found of assistance. It is a photograph of a coil made in the way we are about to describe.  $L_1$ , the aerial winding, is the small one at the bottom of the former;  $L_2$ , the grid winding, is the middle one, with most turns; while the third winding is the reaction or plate one. A glance at the photo will show that all of them are wound in the same direction. Our picture does not show which pins are used for which windings. This has been done on purpose, so that the builder himself will have to use a little initiative in the matter. Obviously, it does not matter at all which pins are used for what, as long as the same arrangement is

used for all coils made, and as the connections made to the coil socket connect the various windings to the right points of the circuit.

### IMPROVEMENTS NECESSARY FOR SHORT-WAVE SET

In order for a short-wave set to be easily manageable, certain improvements are necessary compared with the broadcast set using the same circuit, but we are not going to re-design the whole of the original set at this stage, because the best way to see the need for the said improvements is to build the short-wave coils, substitute them in the old set, and then to observe what difficulties crop up. Some of the desirable modifications are electrical and some are mechanical, such as are entailed in using different materials for the chassis and front panel. We will come to these points in due course, when we have to discuss the operation of the new set. In the meantime, we will continue with the description of how to perform the modifications needed simply to make the set operate on some of the shorter wavelengths.



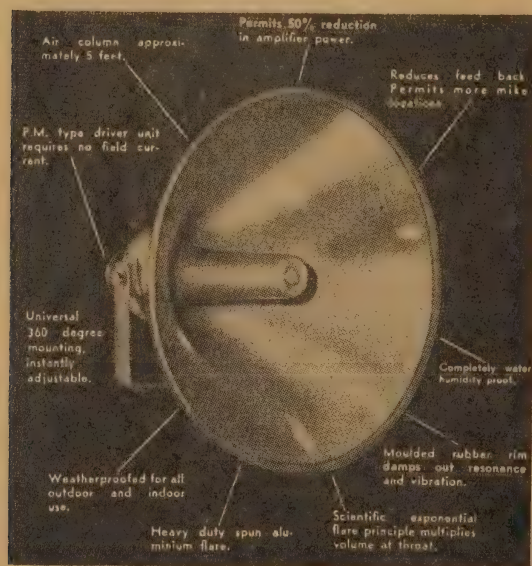
Fig. 29.

### COIL SPECIFICATION

Having seen how the old valve base is used as a coil former, all that remains is to find how many

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turns are needed on the various windings. For this we will refer to Figs. 28 and 29, the detector grid-coil,  $L_2$  on Fig. 28, and the centre winding on Fig. 28. It is the size of this winding that determines the frequency range of the set, since it is tuned by  $C_1$ . It consists of 15 turns of 24 or 22 gauge D.C.C. wire, close-wound. The aerial winding,  $L_1$ , is at the bottom of the former in Fig. 29, and has five turns of 30 gauge enamelled wire, also close-wound, and spaced one-eighth of an inch from the lower end of  $L_2$ . The reaction coil,  $L_3$ , is at the top in Fig. 29, and consists of five turns of the same wire as  $L_1$ , close-wound, and spaced by a quarter of an inch from the top of  $L_2$ .

### WINDING THE COILS

In order to wind the coils it is necessary to make suitable holes in the former. For this purpose an awl is the best instrument, and should be sharpened until the flat cutting edge is not more than one-thirty-second of an inch wide. If an awl is not available, the large (eye) end of an old darning-needle can be used instead. The plastic material of which the valve base is made is quite easy to drill with the bit of needle held firmly in a pair of pliers. The first winding that should be put on is the aerial coil,  $L_1$ . This is simply because it is at the bottom, and putting it on first makes it easier to thread the wire through the small holes in the former and through the valve-pins. Having decided which pins are to be used to terminate the aerial coil, a hole is drilled in the former directly above the pin to be used for the bottom end of the winding. The wire is then threaded through the hole from the OUTSIDE, and passed through the valve pin. It is as well before doing this

to clean off the enamel from the end of the wire so that it will be ready for soldering as soon as it has been threaded through. The soldering is then done, which firmly fixes the end in place. The wire can then be pulled hard in order to make the coil tight, without any possibility of its slipping. Next, the required five turns are wound on, and are carefully held in place while a hole is made through which the finishing end can be passed for final fixing. After the hole has been made, the next step is to bare a length of the wire, cut it off, leaving a few inches to spare, and then thread it through the hole in the former, and through the valve pin that is to be used to terminate the winding. The wire is then held in firm tension while the end is soldered, and the winding is completed. Putting on the remaining two windings is done in exactly the same way as described for the aerial coil. After a little practice, it will be found quite easy to put on the windings, and to have them very tight at the finish, but it is always a good plan to give the completed coil a coat of shellac varnish after winding is completed, as this holds the wire firmly in place, even if it has been wound a little loosely. The reaction winding should not be fixed in this way until the coil has been put into operation, because it is often necessary to make individual adjustments to this. The reason is that different mechanical layouts, and such things as the exact length of some of the leads, often make it impossible exactly to specify the number of turns needed on the reaction coil.

(To be continued.)

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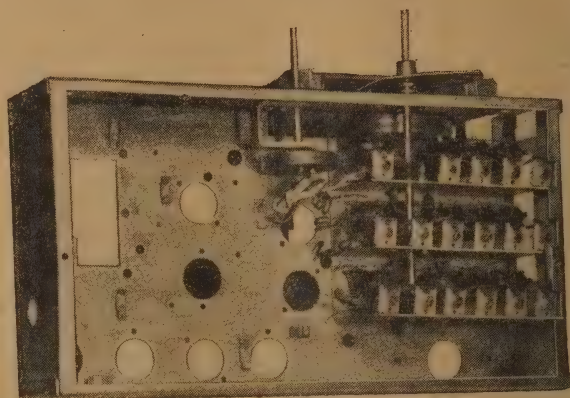
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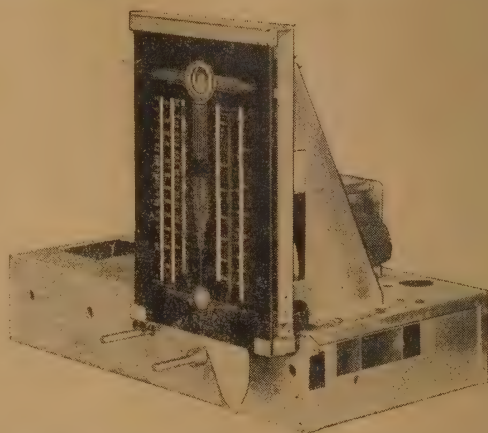
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## THE EDITOR'S OPINION

### A Permeability-tuned I.F. Transformer by Messrs. Swan Electric Co. Ltd.

The Swan Electric Co., Ltd., is in production with a new design of I.F. transformer for the range 450 to 490 kc/sec. It is mounted in an aluminium can  $1\frac{1}{2}$  in. square and  $3\frac{1}{4}$  in. high, and has both tuning adjustments mounted on one side. The leads are of P.V.C. covered stranded wire with tinned ends bared ready for wiring into the set.

results in good high-frequency response in the receiver. In order to check on the coupling and therefore on the band-pass characteristics of these transformers, a receiver was taken in which both I.F. transformers were of the type under examination, and which used a quite conventional arrangement in the I.F. amplifier and 2nd detector portions of the circuit. A frequency-modulated oscillator and an oscilloscope were used to display a picture of the overall resonance curve of the receiver under various conditions. Representative patterns were photographed, and are reproduced here to show the results that can be expected in any normal circuit

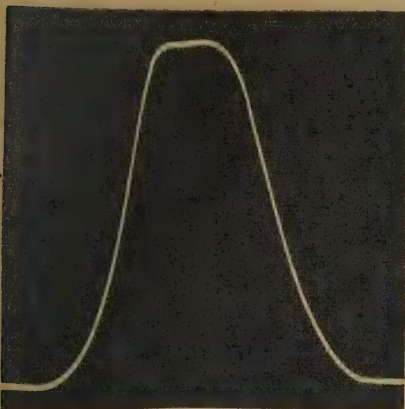


Fig. 1.

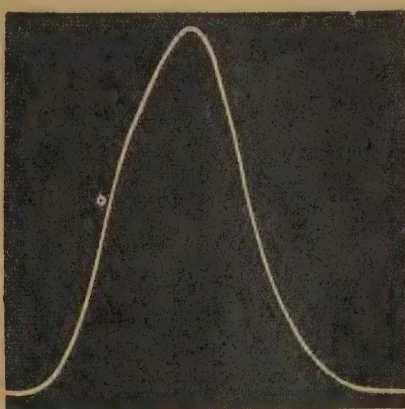


Fig. 2.

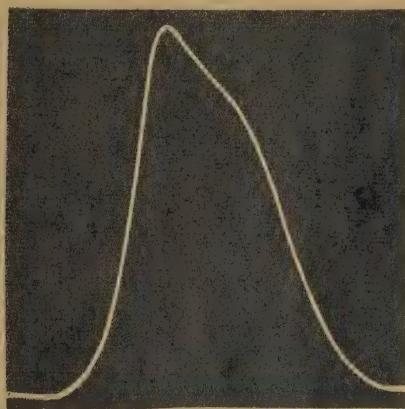
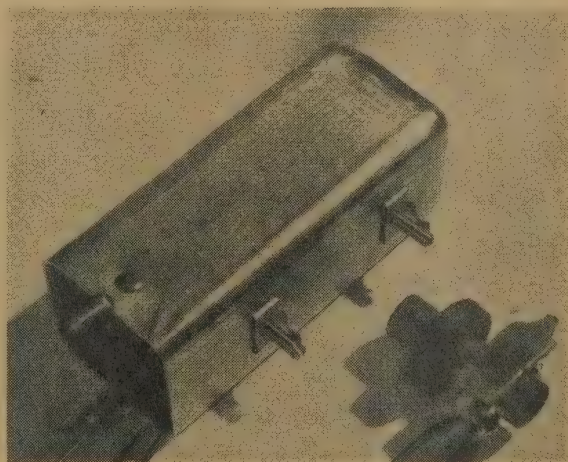


Fig. 3.

### ELECTRICAL PERFORMANCE

A sample transformer was taken without special choice from the production line and was tested by means of a commercial type of Q-meter, and with a frequency modulated oscillator and oscilloscope. First of all, one of the coils was taken from the can, together with its iron-dust core, and the fixed condenser was unsoldered. The coil was connected to the Q-meter, and at a frequency of 465 kc/sec. gave a Q of 170. Next, the condenser (100 mmfd.  $\pm 5\%$ ) was connected, and the Q measured again. This gave a figure of 165. The coil and condenser were reassembled, replaced in the can, and a further measurement taken. This last, which is perhaps the figure of most interest to users, was 145. This is an excellent figure, and shows that the winding tested had a dynamic resistance at resonance of somewhat over 450,000 ohms, which indicates that in an I.F. amplifier stage the valve gain will be of the order of 320 times, from grid to plate, assuming a tube with a mutual conductance of 1.6 ma./v. This figure should not be confused with the stage gain, which is always lower in the I.F. stage with the normal double-tuned transformer than can be realized when a single tuned circuit is used with capacitive coupling to the next grid. By way of comparison, it may be pointed out that a transformer whose circuits are identical to the one tested, but with a Q of, say, 100, would enable a valve gain of only 220 to be obtained. A further advantage of having high-Q circuits in an I.F. transformer is that this enables the selectivity to be made high, while at the same time, by proper attention on the designer's part to the degree of coupling between the windings in the transformer, a good band-pass characteristic is obtained, which in turn



arrangement. Fig. 1 shows the effect when the I.F. stage is properly aligned. It will be noticed that the response curve has an essentially flat top. The frequency scale is not shown, but some idea of this can be obtained from the fact that the band-width at half the distance between the top and bottom of the picture is approximately 20 kc/sec. Thus, the flat top can be seen to extend to plus and minus 5,000 c/sec. from the centre frequency, and that the audio response from the set must therefore be "flat," too, up to this frequency, falling off to 6 db. down at 10,000 kc/sec., and very rapidly thereafter. The transformers can thus be expected to give a good account of themselves from the points of view both of radio quality and of adjacent channel selectivity.

Figs. 2 and 3 show what happens when one winding only is detuned on either side of resonance. It can be seen that the curve becomes too sharply peaked in each case, and that the skirts of the curve remain of identical width. This shows that the only result of the accidental detuning of one winding is to limit somewhat the high-frequency audio response, while leaving unaffected the set's ability to separate unwanted signals from the desired one. This is a most important point where good performance over long periods is concerned.

The tuning range of the sample was tested in the Q-meter by allowing 5 mmfd. for valve and wiring capacities, and setting the calibrated condenser to this value plus the nominal 100 mmfd. capacity of the fixed condenser. The tuning slug was then moved to the extreme positions in turn, and at each, the resonant frequency was read off by adjusting the oscillator of the Q-meter. This gave a figure of 445 to 495 kc/sec. for the actual tuning range. It is noteworthy that the nominal range, quoted earlier, was slightly exceeded at each end, a valuable feature where the transformers are required to tune to non-standard values of intermediate frequency.

### MECHANICAL CONSIDERATIONS

In the design of electrical equipment of any kind mechanical considerations are often of even greater importance than purely electrical ones. This fact seems to have been recognized by the designer of these transformers as evinced by the excellent rigidity that has been achieved in mounting the

coils, and from a close inspection of their construction. For example, the frequency range has been limited to the figures quoted by limitation of the range of movement of the slugs. The latter are a neat fit in the bakelized formers, with the result that all sideways play or "sloppiness" has been eliminated without making the slugs difficult to adjust, through tightness. Before the coils and their slugs are mounted in the can, a piece of bakelized tube, smaller in diameter than the slug itself, is slipped over the threaded shaft of the slug. This piece of tube limits the travel of the core in an outward direction, and serves, first, to limit the frequency coverage, and secondly, to prevent the core from coming into contact with the connecting lugs, which are mounted at that end of the former. The iron-dust core material is theoretically non-conducting, but this precaution prevents trouble should it not be, in which case the coil might otherwise become short-circuited. A spring clip serves the double function of holding the winding in place and keeping a fairly high pressure on the threaded shaft of the slug so that once the latter has been adjusted, there is no possibility of its shifting through vibration or other mechanical disturbances. The chance of mis-alignment from such causes as the above is therefore quite remote.

In brief, it is apparent that these transformers can be readily recommended for either new or replacement use where stability, good band-pass characteristics, and high adjacent-channel selectivity are required.



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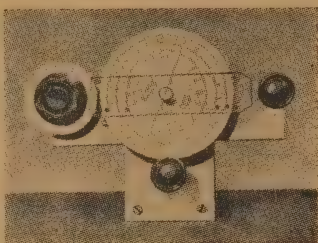
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# The PHILIPS Experimenter

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## No. 6—A CONVERTER FOR THE HIGH-FREQUENCY AMATEUR BANDS

This month's Experimenter will, we hope, serve the dual purpose of illustrating one of the uses to which the new EFF51 double R.F. pentode can be put, and at the same time present some new ideas in the way of construction and performance for frequency bands higher than 30 mc/sec.

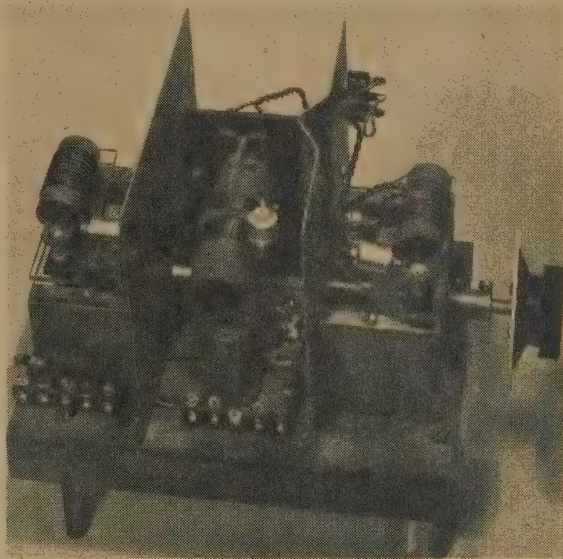
The EFF51 has been designed specifically for V.H.F. and U.H.F. work, and possesses a number of features not found in any other pentode which is intended to be used for radio frequency amplification. Some of these features were discussed briefly in the Philips Experimenter No. 5, and may be briefly outlined as follows:—The effects of cathode lead inductance at high frequencies are minimized in this valve firstly by virtue of its all-glass construction, which allows not only the cathode lead, but in fact all leads to be made much shorter than usual. Secondly, it is well known that when two matched valves are used in a push-pull circuit, signal currents from the two valves in the common cathode lead are equal in amplitude and opposite in phase, with the result that they cancel out, leaving a net R.F. current of zero in this lead. By combining two identical pentodes in the one envelope, it is possible to make the individual cathode leads exceedingly short, after which the length of the common portion of cathode lead is immaterial. This has been done in the EFF51, so that we have a tube specially designed for use in push-pull circuits, and in which the cathode lead inductance probably has less effect than in any other valve made. In addition, each section has the phenomenally high mutual conductance of 11 ma./v., and the outstandingly low equivalent noise resistance of 600 ohms. These things make the tube particularly suited to V.H.F. use, not only as an R.F. amplifier, but also as a superheterodyne mixer, in which role we find it here.

### THE EFF51 AS A MIXER

A glance at the circuit will show that the valve is used as a push-pull mixer. That is to say, the signal is fed to the grids in push-pull by means of a tuned circuit that is balanced to ground. Similarly, a special I.F. output transformer is used, and this, too, is balanced, similarly to a push-pull output transformer used at audio frequencies. Incidentally, would-be constructors need have no fear that this I.F. transformer will cause difficulty in procurement, for it is very easily constructed, working as it does at a frequency of 4 mc/sec. The oscillator voltage is injected into the cathode circuit of the EFF51 via its un-bypassed cathode resistor of 10,000 ohms. This is equivalent to introducing oscillator voltage in phase to both grids simultaneously. The push-pull connection has the advantage that oscillator voltages appearing in the plate circuit are in phase at the plates, with the result that they cancel in the output transformer, much as do second harmonic components in the output transformer of a push-pull audio frequency stage.

## OTHER ADVANTAGES OF PUSH-PULL MIXING

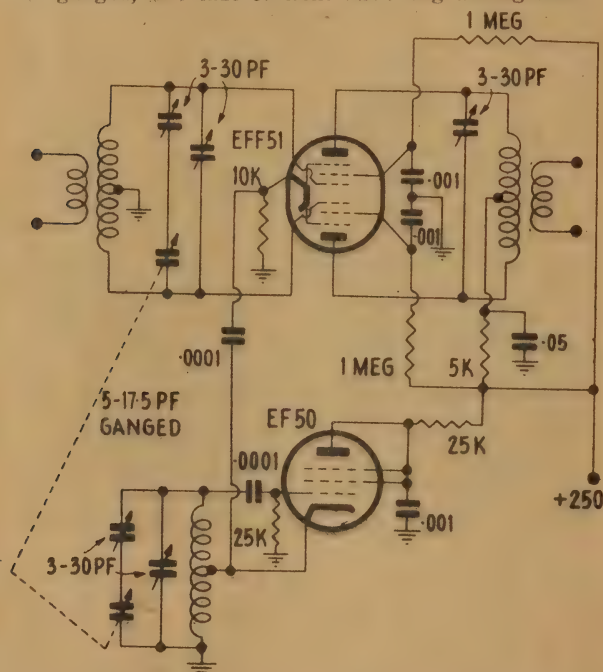
The push-pull connection has other advantages as well as those that have already been mentioned. Chief among these are the reduced input capacity and input loading. At high frequencies, the grid circuit of any valve cannot be regarded as having a high impedance, such as the same valve would show at low frequencies. Not only is the input capacity



quite large compared with the total capacity required for tuning the grid circuit, but there is also a resistive component of input impedance which has a serious effect on the valve's performance. This resistance is not constant, but is inversely proportional to the square of the frequency, so that when the frequency is doubled, the valve loading is four times its original figure. This makes it very difficult to design an input circuit with a high Q under working conditions, at very high frequencies. The effect is well to the fore when ordinary tubes are used at frequencies of 30 mc/sec. and higher, and it is a characteristic of special high-frequency valves such as the EF50, EF54, and EFF51 that their input loading for a given frequency is much lower than that of other valves. This leads us to the fact that here again we have a distinct advantage in using two tubes in push-pull. The reason is simply that here we have TWICE the input resistance of one tube shunted across the tuned circuit. In other words, the loading is only half what it would be in a single-ended circuit using a similar valve. This in turn enables the Q of the input circuit to be raised to a reasonable figure without having to resort to so great a value of tuning capacity. Thus, at high frequencies we are no so limited in our coil design by the fact that high C, used in order to achieve

high  $Q$ , results in an impractically small value of inductance for the tuning coil. Just as the input resistance is halved by the push-pull connection, so is the effective input capacity, since the capacities of the individual tubes are in series across the coil. This also gives better stability to the characteristics of the input tuned circuit, because with a lower input capacity, the proportion of valve capacity and strays to the total capacity needed is rendered smaller. Thus changes in valve input capacity due to replacements or to other causes, such as A.V.C. action, have less detuning effect. From the above it will be seen that the advantages to be found in the push-pull mixer or R.F. amplifier make quite a formidable list. It may be wondered why such circuits are so rarely seen in commercial equipment. The answer is, of course, that they increase the complexity and cost of a receiver, especially when there are circuits to be ganged, and that efficient switching arrangements

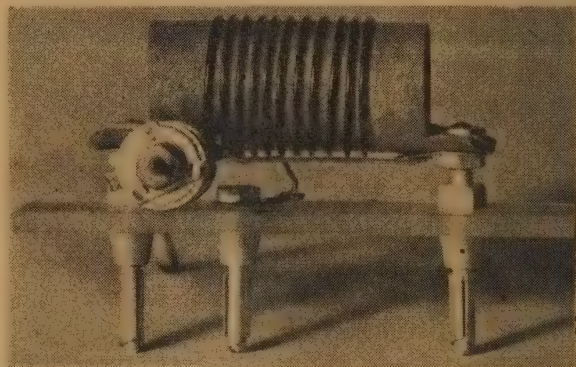
the photo. Across the EFF51 socket, which is the front one, is placed a vertical shield partition. This has a V-shaped bend in it made so that the apex of the V comes directly over the centre hole in the socket, and the arms of the V are at such an angle that the metal passes between the grid and screen pins. Thus, inside the V are found the three pins which connect to the grids and the common cathode and suppressors. At right angles to this shield partition are two vertical pieces of metal with flanges at their top edges. These act as supports for a shelf



are more difficult to make, and require more wafers per stage. It is worth-while mentioning in this connection that a well-known British radar receiver, which was designed in 1938 or 1939, long before the EFF51, used two push-pull R.F. stages and a push-pull mixer! The first stage used a pair of Philips' low-noise EF8's. This was a case where the best possible performance had to be obtained, and where space allowed band-switching to be done by using complete duplicate R.F. and oscillator-mixer channels.

### CONSTRUCTION

The lay-out of the experimental model is somewhat unconventional, as can be seen from the photographs. The chassis consists of a simple sheet of steel, cadmium plated, with no ends, and with the sides turned down to give rigidity. The valves are mounted upside down on the centre-line of the chassis, and the whole unit is supported on legs which are tall enough to prevent the tubes from resting on the case, which has not been shown in



made of  $\frac{1}{8}$  in. perspex. This supports both the midget tuning condenser and the sockets for the plug-in coils. The mounting of the oscillator condenser and coil is similar except for the fact that the main shield partition in this case has no V-shaped bend. Also the partition does not cross the EF50 socket, but is mounted in front of it. The variable condensers have to be mounted on insulating material because both sides are at R.F. potential above ground. The components in which they are mounted are purposely made fairly large so that the capacity to ground of the stator and frame of each condenser will not be any larger than necessary. This helps to preserve the balance in the push-pull input circuit. The shafts of the condensers are coupled by means of a piece of polystyrene rod. Flexible couplings need not be used between this and the condenser shafts if the mechanical work is accurately enough carried out.

### OUTPUT TRANSFORMER

As was mentioned above, the I.F. for this converter is 4 mc/sec. The output is taken to the main receiver from a small link wound over the centre of the balanced primary. The latter is tuned by a 3-30 mmfd. Philips trimmer. The output circuit is to be seen in the photograph between the two shield partitions. The coil is mounted on a vertical strip of ebonite which can also be seen.

This is wound with 54 turns of 22-gauge enamelled wire, close-wound on a 1 in. o.d. former. The secondary consists of two turns of P.V.C. hook-up wire wound over the centre of the primary, which is tuned with a 3-30 mmfd. Philips trimmer.

### AERIAL AND OSCILLATOR COILS

These are wound on bakelized formers which are in turn mounted on Belling-Lee "banana" plugs that are mounted on a strip of  $\frac{1}{8}$  in. perspex, similar to the material used as insulating shelves for supporting the tuning condensers and "banana" sockets. The construction of the oscillator coil is clearly shown by the photograph. (Continued on next page.)

## OUR GOSSIP COLUMN

George Ferris, genial fisherman from the South, has been visiting Wellington.

\* \* \*

The record for the "hat trick" goes to Norm Swann. No doubt meditating about his overseas trip, Norm left his office in a hurry one day and picked up a hat which he later discovered to be not his own. However, assuming that it belonged to "Brig" Mason, Norm was not unduly disturbed. After paying a visit to the American Embassy, he noticed that either the hat was much smaller in size, or else his head had become much larger as a result of a satisfactory interview. However, being quite unconcerned about the alarming implications of the latter, he returned to his office to find a tremendous search in progress for the missing hat of a visitor who was being shown through the factory. Immediately realizing what had happened, Norm apologized profusely, and gallantly removing the hat from his head proffered it to the visitor. To his horror, however, an investigation showed that he had exchanged hats once more at the American Embassy. As a result, he is now poorer by 50/- for the visitor's hat, and meanwhile is endeavouring to locate the owner of the second hat.

\* \* \*

Mr. Brehaut of Brehauts Radio Service, Timaru, has been in Wellington on business recently.

\* \* \*

Maurie O'Sullivan and Frank Hayhurst, National Carbon Representatives, were around Wellington when Mr. Huffard was here.

\* \* \*

Norm Swann, Managing Director of Swan Electric Co., Ltd., has left New Zealand on a business trip to England. Norm expects to be away for two or three months, and will return via the United States. Mrs. Swann is accompanying her husband on his tour.

\* \* \*

Mr. Paul P. Huffard, Vice-President of the Union Carbide and Carbon Corporation of New York, of which National Carbon Pty. Ltd., Wellington, is a New Zealand subsidiary, was a recent visitor to the Dominion.

Mr. Huffard, who left Auckland on Tuesday, 17th February, has completed a world tour of his firm's plants. From the United States he flew to England, France, Egypt, India, Malaya, Batavia, Australia, and arrived in Auckland on 28th January, flying direct to Invercargill, from which centre he travelled by car through both the South and North Islands. Opportunities were taken whilst in Christchurch, Wellington, and Auckland of meeting various executives of those firms which act as distributors for "Eveready" products.

\* \* \*

Mr. Greenwood, Managing Director of National Carbon Pty. Ltd., who accompanied Mr. Huffard during his tour, tells us that Mr. Huffard was greatly impressed with what he had seen of New Zealand and hopes to pay another more leisurely visit at some future date.

## NEW PRODUCTS

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## PHILIPS EXPERIMENTER

(Continued from previous page.)

### AERIAL COIL SPECIFICATIONS

Band	Turns
10 m.	11
6 m.	5
20 m.	22

Note: All coils wound on ½ in. o.d. former with 20-gauge en. wire, double-spaced and centre tapped.

### OSCILLATOR COILS

Band	Turns
10 m.	10, tapped at 2 from earth end.
6 m.	4, tapped at 1 from earth end.
20 m.	18, tapped at 4 from earth end.

### ADJUSTMENT OF BANDSPREAD

Full bandspread is realized on 10 metres by the use of series and parallel trimmers in both mixer and oscillator circuits. The capacity variation of the ganged condensers is too great, so that the series condensers have to be used to reduce the amount of variation. The proper adjustment of the condensers is not difficult, but requires care and systematic procedure. The best plan is to start with the oscillator, feeding signal frequency in to one side only of the push-pull input circuit so that the tuning of the latter will have not much effect at this stage. A signal is fed in at 30 mc/sec., after the output transformer has been set to its correct frequency of 4 mc/sec. Then the series oscillator trimmer is set to about one-third capacity, and the signal is tuned in by setting the gang at minimum capacity and tuning with the oscillator parallel trimmer. When the signal has been found, the gang is turned to maximum capacity, and the signal generator is gradually tuned lower in frequency until a signal is heard again whose frequency is read off. This tells whether the bandspread is too great or too small.

If too small, a reduction in the value of series trimmer is indicated, and vice-versa. A small change is therefore made in this condenser, the gang is returned to minimum, the signal generator is returned to 30 mc/sec., and the signal tuned in again with the parallel trimmer. The frequency at the other end of the band is now found as before. This process is continued until the tuning range is as close as desired to the exact limits of the band. After this the input circuit can be adjusted until it is found to track with the oscillator section, which must not now be touched. If the coils are wound according to specifications, the settings for the aerial circuit trimmers will correspond quite closely to those of the oscillator ones, so that similar settings can be used as a starting point. It is simply a matter of adjusting the aerial trimmers until there is no noticeable variation of sensitivity over the band.

## 10 AND 20 METRE BEAM

(Continued from page 18.)

grounded directly to earth. In this installation only the two radiators were grounded as it was felt that this offered sufficient protection. This was done by connecting the centres of both radiators together with No. 10 wire which was connected to the vertical pipe. A flexible contact is then provided from the vertical pipe to a ground wire running directly to a copper ground rod.

Signal reports all over the world have been good — R9 reports on all continents have been received on phone. A total of 51 countries have been worked with this system using 250 watts of input and operation on the 10 and 20 metre bands is now most enjoyable in spite of the QRM.

Plans were begun for a phased array for 40 and 80 metres, but after one look at the 20-10 beam on the roof, the XYL firmly decided that she would emphatically impede any research along these lines, so BCNU on 20 and 10 metre phone.

## THE SYNCHRODYNE

(Continued from page 34.)

### CONCLUSION

The three receiver designs given here should give the reader a sufficiently good idea of how a synchrodyne can be built for various purposes. It is hoped therefore that readers will be able to modify these designs to suit their own requirements, and that they will form a basis for experimental work along the lines suggested in an earlier article.

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## TONE CONTROL SYSTEMS

(Continued from page 14.)

for the middle frequencies and a very big bass lift. One point worthy of mention is that the grids of the double triode are de-coupled to earth, as shown, to prevent any signal being fed to the grids from the cathode which would cause an unbalanced output from the anodes.

## HARD-VALVE LINEAR TIME-BASE

(Continued from page 8.)

condensers of 20 per cent tolerance, quite large gaps can occur.

In the experimental work on this device, no attempt was made to extend the working range to very high frequencies. With the constants shown, there was no difficulty in getting it to work well up to 20,000 c/sec., which is ample for most purposes, especially when the time-base is so stable in operation. One of the most pleasing things about its performance was the way in which it gave identical pictures, without any trace of distortion or worsening of the flyback, whether it was at 20 c/sec. or 20,000.

### USING THE BLACKOUT WAVEFORM

At the plate of  $V_1$  is a square-wave identical with the switching waveform of  $V_2$  except for the fact that it is reversed in phase. In the case of  $V_1$ , the positive-going portion corresponds in time to the flyback. The waveform can therefore be used by applying it to the cathode of the C.R.T., when it will cut off the beam during the flyback, and allow it to show during the forward stroke. To do this one must have a tube whose cathode is brought out to a separate pin on the base. Many American tubes have the cathode tied internally to one side of the heater, and so make it impossible to utilise the cathode in this way. However, if one has this kind of tube, and it is desired to black out the flyback, it can be done by taking the output of  $V_1$  to an amplifier tube, which will reverse its phase, so that it can be fed on to the grid of the tube. When applying a blackout waveform, whether to grid or cathode, it is important to inject only just enough voltage to make the return trace invisible, and no more. If too great a voltage is fed in, the waveform not only blacks out the flyback, but also causes a large increase in the brilliance of the trace proper. This is because it makes the grid more positive during the trace, and the effect can render the normal brilliance control ineffective, as well as being bad for the tube. The best possible precaution is to instal a D.C. restorer across the grid-cathode circuit of the tube, but this means providing a separate heater winding for the restorer tube. However, all will be well as long as the injected voltage is kept down to the point where the flyback is only just obliterated.

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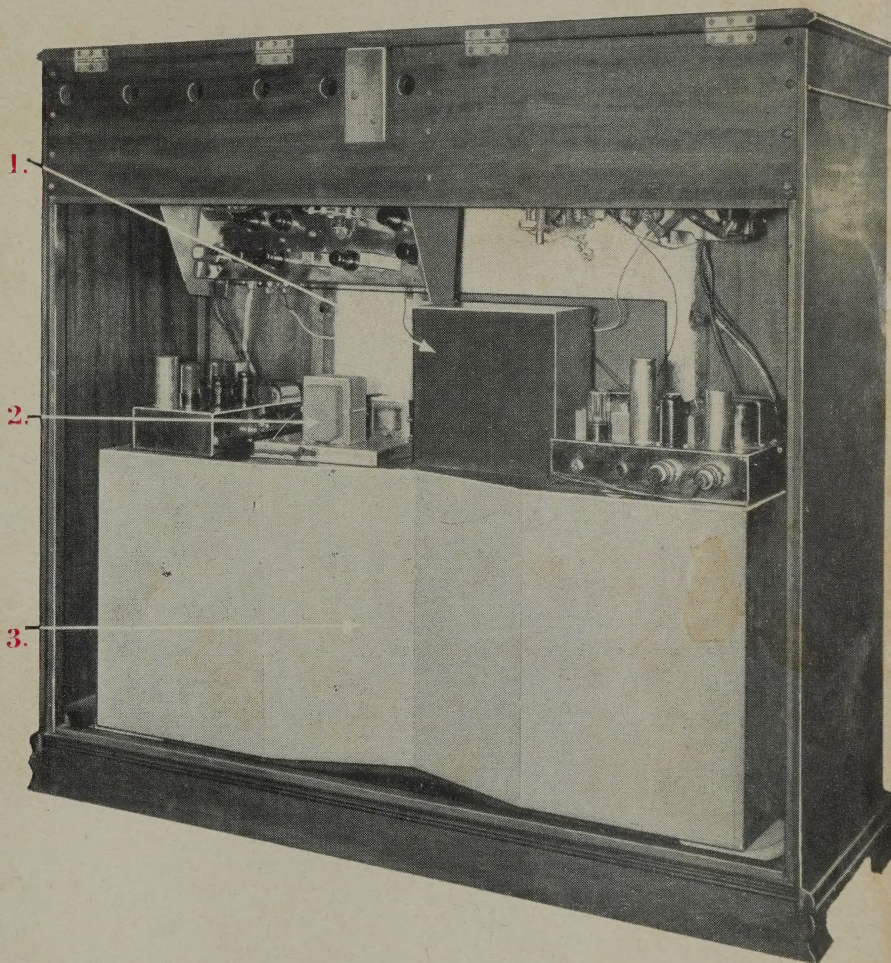
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